



Original Contribution

Impact of an emergency medicine pharmacist on empiric antibiotic prescribing for pneumonia and intra-abdominal infections☆



Benjamin D. Kulwicksi, PharmD^{a,1}, Kasey L. Brandt, PharmD^a, Lauren M. Wolf, PharmD^a, Andrew J. Weise, MD^b, Lisa E. Dumkow, PharmD^{a,*}

^a Pharmaceutical Services, Mercy Health Saint Mary's, Grand Rapids, MI, USA

^b Grand Rapids Emergency Medical Group, Grand Rapids, MI, USA

ARTICLE INFO

Article history:

Received 6 June 2018

Received in revised form 24 July 2018

Accepted 26 July 2018

Keywords:

Empiric antibiotics

Pneumonia

Intra-abdominal

Pharmacist

Stewardship

Emergency Department

ABSTRACT

Purpose: It is critical to engage ED providers in antimicrobial stewardship programs (ASP). Emergency medicine pharmacists (EMPs) play an important role in ASP by working with providers to choose empiric antimicrobials. This study aimed to determine the impact of an EMP on appropriate empiric antibiotic prescribing for community-acquired pneumonia (CAP) and intra-abdominal infections (CA-IAI).

Methods: A retrospective cohort study was conducted evaluating adult patients admitted with CAP or CA-IAI. The primary outcome of this study was to compare guideline-concordant empiric antibiotic prescribing when an EMP was present vs. absent. We also aimed to compare the impact of an EMP in an early-ASP vs. established-ASP.

Results: 320 patients were included in the study (EMP $n = 185$, no-EMP $n = 135$). Overall empiric antibiotic prescribing was more likely to be guideline-concordant when an EMP was present (78% vs. 61%, $p = 0.001$); this was true for both the CAP (95% vs. 79%, $p = 0.005$) and CA-IAI subgroups (62% vs. 44%, $p = 0.025$). Total guideline-concordant prescribing significantly increased between the early-ASP and established-ASP (60% vs. 82.5%, $p < 0.001$) and was more likely when an EMP was present (early-ASP: 68.3% vs. 45.8%, $p = 0.005$; established-ASP: 90.5% vs. 73.7%, $p = 0.005$). Patients receiving guideline-concordant antibiotics in the ED continued appropriate therapy upon admission 82.5% of the time vs. 18.8% if the ED antibiotic was inappropriate ($p < 0.001$).

Conclusion: The presence of an EMP significantly improved guideline-concordant empiric antibiotic prescribing for CAP and CA-IAI in both an early and established ASP. Inpatient orders were more likely to be guideline-concordant if appropriate therapy was ordered in the ED.

© 2018 Elsevier Inc. All rights reserved.

1. Introduction

The Emergency Department (ED) serves as an important bridge between ambulatory and inpatient care and represents an important target for antimicrobial stewardship interventions aimed at decreasing inappropriate antimicrobial use [1, 2]. More than 100 million patients are treated annually in EDs throughout the United States with an estimated 16% of these patients receiving antibiotics [3–5]. In addition, it has been estimated that up to 50% of all antimicrobial use is

inappropriate [6–8]. Antimicrobial stewardship programs (ASPs) promote appropriate antibiotic prescribing across healthcare settings which is critical to combat the increasing rates of antimicrobial resistance, improve patient outcomes, and manage the rising costs of healthcare [9, 10].

Due to the high volume of antimicrobial prescribing it is critical to engage ED providers in ASPs. Additionally, pharmacists play a prominent role in ASPs, with the most successful programs promoting collaboration between pharmacist and physician stakeholders [11–13]. In 2011, the American Society of Health-System Pharmacists Association published guidelines for emergency medicine pharmacist services recommending that EMPs be involved in direct patient care rounds and medication order review [14]. The purpose of this study was to determine the impact that EMPs have on the appropriate selection of empiric antibiotic therapy for community-acquired pneumonia (CAP) and community-acquired intra-abdominal infections (CA-IAI). This study also aimed to examine the combined ASP and EMP impact on antibiotic prescribing in the ED over time. We hypothesized that the presence of an EMP would improve empiric antibiotic prescribing and that

Abbreviations: CAP, Community-acquired pneumonia; CA-IAI, Community-acquired intra-abdominal infection; ID, Infectious diseases; ED, Emergency Department; EMP, Emergency medicine pharmacist.

☆ The authors have no actual or potential conflict of interest in relation to this manuscript.

* Corresponding author at: Mercy Health Saint Mary's, 200 Jefferson SE, Grand Rapids, MI 49503, USA.

E-mail address: lisa.dumkow@mercyhealth.com (L.E. Dumkow).

¹ Present Address: Pharmaceutical Services, Mercy Health Muskegon, Muskegon, MI, USA.

Table 1
Baseline characteristics.

	EMP present (n = 185)	EMP absent (n = 135)	p-Value
Age, years*	60.5 ± 19.3	59.2 ± 20.4	0.58
Male, n (%)	88 (48)	71 (52)	0.62
Charlson score†	3 (0–10)	3 (0–12)	0.82
Sepsis, n (%)	41 (22.3)	29 (21.5)	0.96
Penicillin allergy, n (%)	34 (18.4)	22 (16.3)	0.65

* Mean ± SD.

† Median (range).

prescribing practices would improve over time as the antimicrobial stewardship program matured.

2. Methods

2.1. Study design

A retrospective cohort study of patients admitted to the hospital through the ED with a diagnosis of CAP or CA-IAI was conducted at a community teaching hospital. The diagnoses of CAP and CA-IAI were chosen for evaluation as they are two of the most common infection-related diagnoses admitted from the ED and were additionally viewed as initial targets for improvement by the hospital's Antimicrobial Stewardship Committee. Two time periods were evaluated in order to compare the impact of an early-ASP (January 1, 2014 to December 31, 2014) to an established-ASP (January 1, 2016 to December 31, 2016). Patients were included if they were at least 18 years of age and were admitted to the hospital following an ED diagnosis of CAP or CA-IAI as documented by the ED provider. Pneumonia patients were excluded from the study if they had an ED diagnosis of healthcare-associated, hospital-acquired, or ventilator-associated pneumonia. Intra-abdominal patients were excluded if they had a diagnosis of healthcare-associated or surgical-associated intra-abdominal infections. Additionally, patients were excluded if they had discrepant ED and inpatient discharge diagnoses, if they were admitted over the weekend (due to inconsistent hours of EMP coverage), left against medical advice, or had a CD4 count of <200 cells/μL.

The primary objective of this study was to determine the appropriateness of empiric antibiotic prescribing in the ED setting when an EMP was present (EMP group) compared to when they were absent (no-EMP group). Empiric therapy was defined as appropriate if it was in concordance with the institution's empiric antibiotic guidelines, which were developed in conjunction with the Infectious Diseases Society of America's CAP and intra-abdominal infection guidelines along

with local susceptibility patterns. The institution's empiric therapy guidelines recommend a third-generation cephalosporin-based regimen as first-line therapy for both CAP and CA-IAI and a fluoroquinolone-based regimen only for patients with a severe beta-lactam allergy. Neither the CAP nor CA-IAI guideline recommend empiric anti-Pseudomonas coverage. Secondary objectives included comparing the appropriateness of empiric antibiotic prescribing in the setting of an early-ASP (2014) vs. established-ASP (2016), evaluating the appropriateness of antibiotics continued upon inpatient admission, and comparing patient outcomes including hospital-onset *Clostridium difficile* infections, in-hospital mortality, and length of stay between groups.

Data collected from patients' medical records included age, sex, Charlson Co-morbidity Index (predictor of 10-year survival for patients with multiple comorbidities), antibiotic allergies and reactions, ED diagnosis, empiric antibiotic selection, time that antibiotics were ordered, presence of an EMP, admitting diagnosis, admitting antibiotic selection, in-hospital mortality, hospital-onset *C. difficile*, and length of stay. The time that antibiotics were ordered was categorized as EMP present or no-EMP. ED clinical pharmacists were considered present between the hours of 1300 and 2300 in the early-ASP and between the hours of 1100 and 2100 in the established-ASP (time difference due to change in EMP schedule which took place in 2015). Final Institutional Review Board approval (#16-1116-5) was obtained on November 18, 2016.

2.2. Study settings and population

The study site is a 350-bed community teaching hospital with a 44-bed ED servicing approximately 72,000 visits per year. ED clinical pharmacy services were initiated in October 2011 with 1.0 FTE EMP covering 40 h per week Monday through Friday. In August 2013 this service expanded to 2.0 FTE EMP covering 70 h per week including weekend coverage. The EMP responsibilities include following: medication order and allergy evaluation, consulting for pharmacotherapy recommendations, assisting during medical emergencies, medication preparation and administration, culture follow-up for discharged patients, and providing education to ED providers, nurses, residents, students, and other staff. Medications are ordered by providers via computerized physician order entry; however, not all ED medication orders are required to be reviewed by a pharmacist prior to dispensing as many common medications, including antibiotics, are stored in the automated dispensing cabinets located in the ED. For those medications located in the ED automated dispensing cabinets, nursing staff and ED clinical pharmacists may remove and administer the medication without prospective pharmacist review. The ED clinical pharmacists utilize the electronic

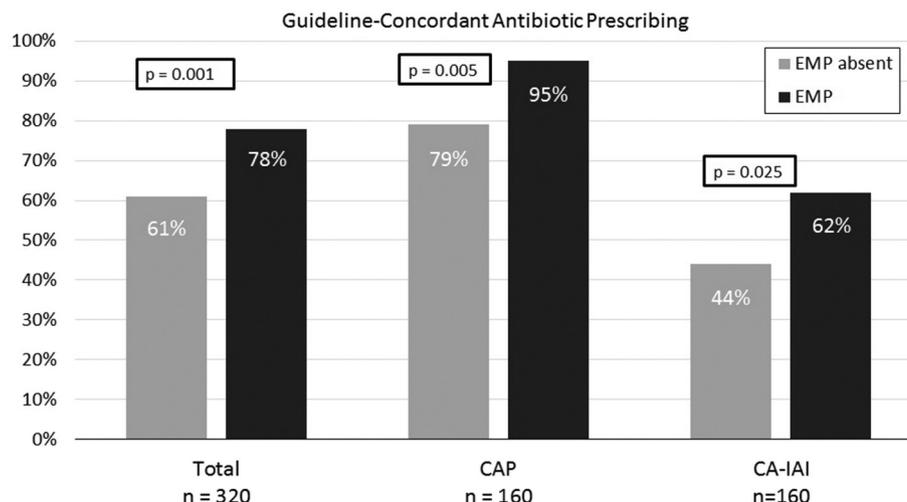


Fig. 1. Guideline-concordant antibiotic prescribing.

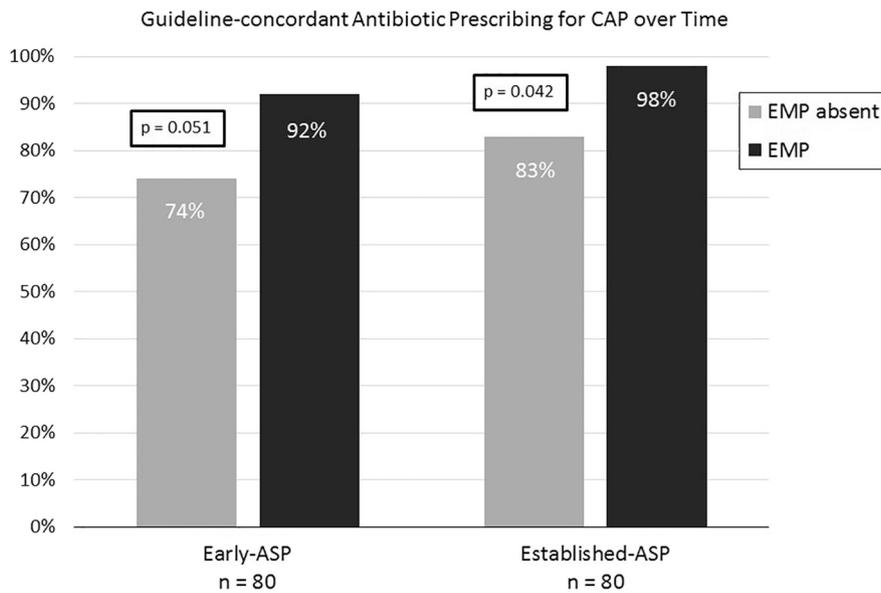


Fig. 2. Guideline-concordant antibiotic prescribing for CAP over time.

tracking board to review medication orders in real-time which allows them to make interventions with nursing and provider staff prior to medication administration.

The hospital's ASP was implemented in October 2013 and is led by 1.0 FTE Infectious Diseases (ID) pharmacist and supported by 0.1 FTE ID physician as well as the Antimicrobial Stewardship Committee. The Antimicrobial Stewardship Committee includes multi-disciplinary membership from different disciplines including an ED physician and both EMPs. The Antimicrobial Stewardship Committee is responsible for annual evaluation of the hospital's antibiogram and uses this data to update the institution's empiric therapy guidelines. The empiric therapy guidelines provide recommendations for both patients who are admitted to the hospital from the ED as well as for those who are discharged to home. The ID pharmacist and ID physician work with members of the Antimicrobial Stewardship Committee to schedule in-person educational sessions for each provider group. Education to the ED provider group occurs at least annually in order to relay information regarding pertinent changes to the antibiogram and empiric therapy guidelines. The ID pharmacist is additionally responsible for providing daily audit-and-feedback to inpatient providers regarding antibiotic orders, with a focus on empiric guideline-concordant antibiotic selection;

this includes follow-up with the ED clinical pharmacists to provide prescriber feedback when discordant therapy is selected in the ED.

2.3. Data analysis

A sample size of 320 patients was estimated to detect a 20% difference in guideline-concordant prescribing between the EMP and No-EMP groups. One hundred and sixty patients meeting inclusion criteria were selected via a computer-generated randomization from both the early-ASP and established-ASP time periods. Eighty patients were included from both the CAP and CA-IAI cohorts in each year. Interval data were reported as medians with ranges and the Student's *t*-test or Mann-Whitney *U* test were used to compare groups based on the distribution of the data. Categorical data was expressed using frequency distributions and compared using the χ^2 test or Fisher's exact test as appropriate. All tests were 2-tailed and a *p*-value of <0.05 was considered statistically significant. Multivariate logistic regression was performed to assess for independent risk factors associated with guideline-concordant antibiotic prescribing for both the CAP and CA-IAI subgroups. Factors with a *p*-value of <0.2 in the bivariate analysis were eligible for inclusion into the model.

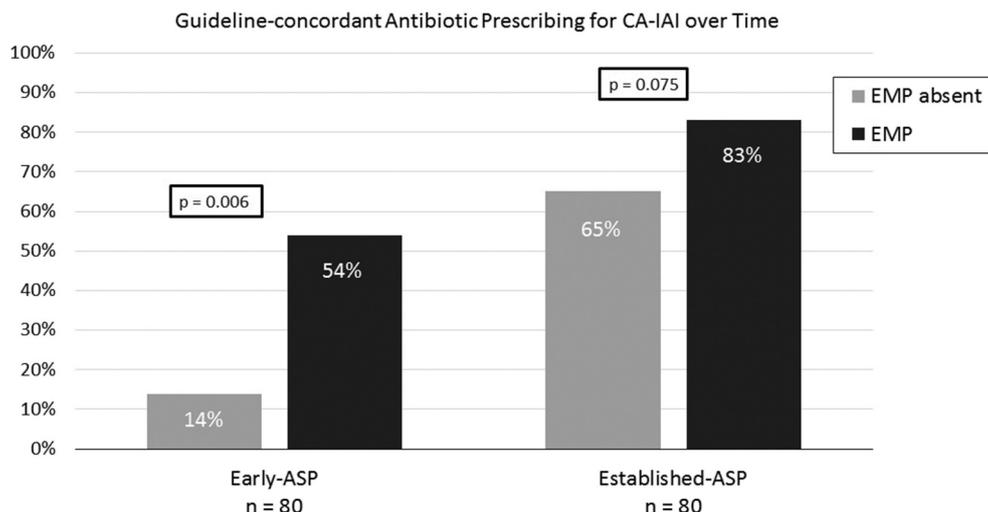


Fig. 3. Guideline-concordant antibiotic prescribing for CA-IAI over time.

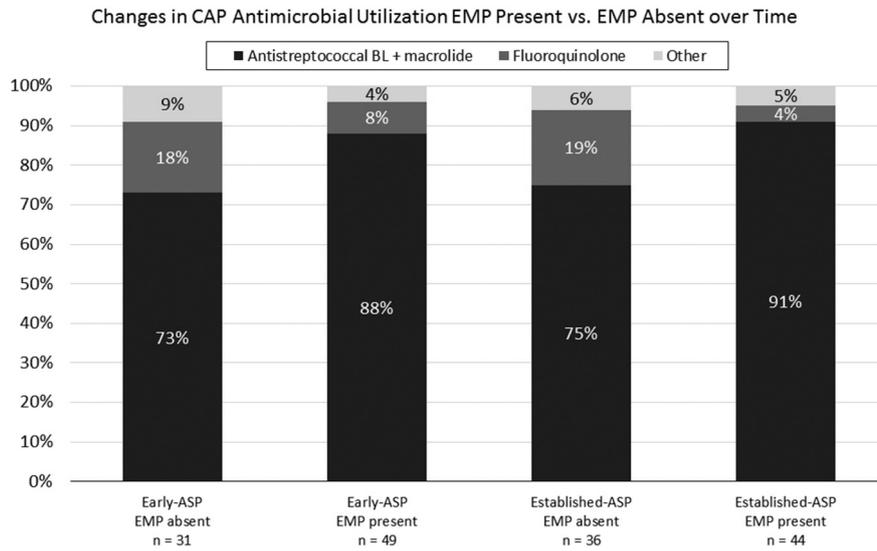


Fig. 4. Changes in CAP antimicrobial utilization EMP present vs. EMP absent over time.

3. Results

3.1. Baseline characteristics and primary outcome

A total of 320 patients were included in the study, 185 patients in the EMP group and 135 in the No-EMP group. Baseline demographics were similar between groups and approximately 20% of patients met sepsis criteria during ED evaluation in both groups (Table 1). Total empiric antibiotic selection was more likely to be guideline-concordant when an EMP was present vs. absent (78% vs 61%, $p = 0.001$). In the sub-group of CAP patients ($n = 160$), guideline-concordant empiric antibiotic selection was significantly improved with the presence of an EMP (95% vs. 79%, $p = 0.005$); guideline-concordant antibiotic prescribing was also significantly improved in the CA-IAI subgroup ($n = 160$) when an EMP was present (62% vs. 44%, $p = 0.025$) (Fig. 1).

3.2. Impact of the antimicrobial stewardship program and ED clinical pharmacists over time

Total guideline-concordant antimicrobial prescribing significantly increased between the early-ASP and established-ASP cohorts (60% vs 82.5%, $p < 0.001$). Antibiotics were more likely to be guideline-concordant when an EMP was present in both time periods (early-ASP: EMP present 68.3% vs EMP absent 45.8%, $p = 0.005$; established-ASP: EMP present 90.5% vs EMP absent 73.7%, $p = 0.005$). This difference was observed for both CAP and CA-IAI groups (Figs. 2 and 3). The differences in antimicrobial prescribing over time are presented in Fig. 4 for CAP and Fig. 5 for CA-IAI. A reduction in fluoroquinolone prescribing was observed over time in the CAP subgroup, and more pronounced when an ED clinical pharmacist was present. The use of empiric piperacillin/tazobactam for CA-IAI decreased over-time as the use of first-line ceftriaxone and metronidazole increased.

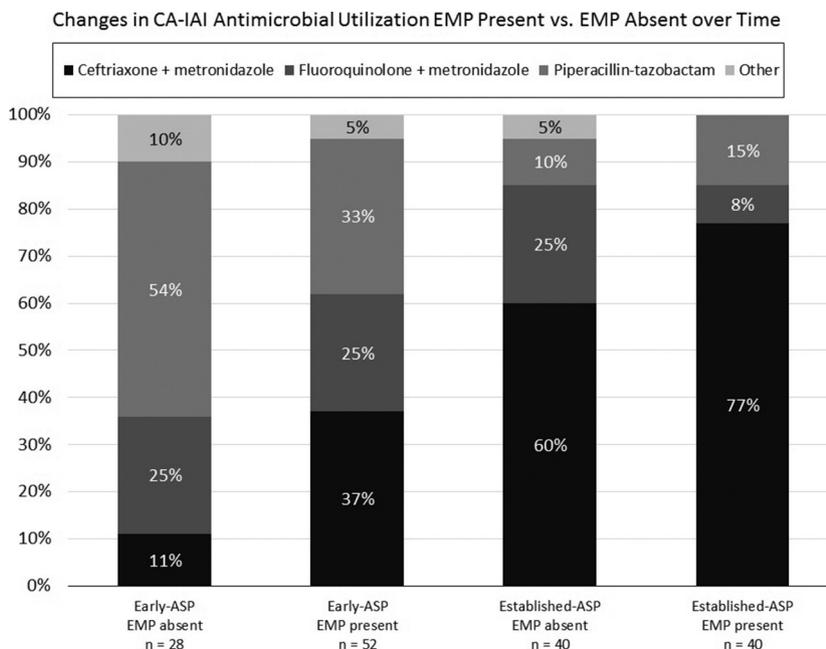


Fig. 5. Changes in CA-IAI antimicrobial utilization EMP present vs. EMP absent over time.

3.3. Impact on inpatient prescribing and patient outcomes

Patients who were initiated on guideline-concordant therapy in the ED continued on guideline-concordant therapy 82.5% of the time. In contrast, patients who did not receive guideline-concordant therapy in the ED had admission orders for guideline-concordant antimicrobials in 18.8% of cases ($p < 0.001$). There was no difference in the secondary endpoints of hospital-onset *Clostridium difficile* infection, in-hospital mortality, or length of stay between the EMP vs. No-EMP groups (Table 2).

3.4. Multivariate logistic regression

Factors included in the model for each disease state are shown in Tables 3 and 4. In the subgroup of CAP patients, the presence of an EMP was the only factor identified to be individually associated with an increase in the rate of guideline-concordant prescribing (OR 4.5, [95% C.I. 1.5–14.1]). Both the presence of an EMP (OR 3.3 [95% C.I. 1.5–7.3]) as well as the maturity of an ASP (OR 7.5 [95% C.I. 3.5–16]) were found to be independently associated with an increase in guideline-concordant prescribing for CA-IAI.

4. Discussion

Our study demonstrates the significant impact of EMPs in improving empiric treatment selection for CAP and CA-IAI. Additionally, this study shows the importance of coupling ED clinical pharmacist activities with ASP initiatives. Total guideline-concordant prescribing significantly increased over time with improved prescribing adherence demonstrated in both the early-ASP and established-ASP groups when an EMP was present. The important role of EMPs in patient care has been recognized by several disciplines across the healthcare system. A 2007 survey of nurses and providers at an academic medical center ED treating over 93,000 patients annually demonstrated a high level of staff acceptance of EMPs. Staff members valued the presence of an ED clinical pharmacist, frequently consulted on cases, and felt they improved the quality of patient care [15]. A similar survey published by Coralic and colleagues in 2014 found that provider and nursing staff felt EMPs contributed significantly to patient safety and that they were more likely to seek out recommendations from EMPs than from staff pharmacists [16]. The American College of Emergency Physicians published a formal policy statement recognizing EMPs as a valuable member of the interdisciplinary team in June 2015 [17]. Additionally, the American College of Medical Toxicology published a statement in October 2017 declaring EMPs integral to providing safe and cost-effective care for adult and pediatric ED patients [18]. Furthermore, EMPs have been recognized as highly valued members of ASPs. In July 2017, the Society of Infectious Diseases Pharmacists published a position statement regarding ED clinical pharmacists' participation in ASPs. The organization highly supports the involvement of ED clinical pharmacists in activities such as culture follow-up, creation of guidelines and clinical pathways, and assistance in empiric therapy selection [19].

To our knowledge, this is the first study evaluating the impact of EMPs on the empiric treatment of CA-IAI. Similar to our study, previous authors have demonstrated improved guideline-concordant antibiotic prescribing for pneumonia in the ED when an EMP is present. Faine and colleagues analyzed the impact of an EMP on antibiotic prescribing for CAP and healthcare associated pneumonia (HCAP) in the ED. Over the 8-year study period the authors found an increase in antibiotic prescribing appropriateness in both groups when an EMP was present vs. absent (58.3% vs 38.3%, $p < 0.001$) [20]. A similar study by DeFrates and colleagues showed improved empiric prescribing for HCAP in the ED when an EMP was present vs. absent (49.4% vs 25.7%, $p = 0.005$). Additionally, a shorter time to antibiotic therapy (11.4 vs 15.6 h) as well as more appropriate doses (85.2% vs 77.1%) were observed in the ED clinical pharmacist group [21]. Furthermore, DeWitt and colleagues

Table 2
Patient outcomes.

	EMP present (n = 185)	EMP absent (n = 135)	p-Value
Hospital onset <i>C. difficile</i> , n (%)	2 (1.1)	2 (1.5)	1.0
In-hospital mortality, n (%)	8 (4.3)	2 (1.5)	0.2
Length of stay, days [†]	2.8 (0.3–23)	2.5 (0.2–15.7)	0.18

[†] Median (range).

found that antibiotics that required renal or weight-based dose adjustments were 6.5 times more likely to be appropriate when an EMP was present [22]. However, these studies did not trend the impact of the EMPs interventions over time. Our study demonstrated a significant improvement in empiric antibiotic prescribing when EMPs were present and this impact was maintained even as the ASP matured.

Antibiotics are the second most common class of medications prescribed in the ED [3]. Judicious antibiotic prescribing is paramount due to increasing rates of antibiotic resistance coupled with the critical importance of appropriate empiric antibiotic selection [23–25]. EMPs are in an ideal position to encourage appropriate empiric prescribing as they can make real-time recommendations for antibiotic selection or intervene and suggest alternatives when inappropriate antibiotics are ordered [14, 19]. Goals of our ASP included the reduction of inappropriate fluoroquinolone prescribing for both CAP and CA-IAI, as well as the reduction of anti-Pseudomonas beta-lactam prescribing for CA-IAI, specifically piperacillin-tazobactam. Our study demonstrated that the presence of an EMP was independently associated with guideline-concordant empiric antibiotic prescribing for both CAP and CA-IAI diagnoses. The receipt of more guideline-concordant, narrow-spectrum therapy in the EMP group did not negatively impact patient outcomes, which is similar to previous literature [20, 21, 25]. Additionally, the maturity of the ASP was independently associated with appropriate antibiotic therapy in CA-IAI. The impact of ASP maturity on empiric prescribing was likely more pronounced for CA-IAI than CAP due to a larger need for improvement in CA-IAI prescribing (44% appropriateness at baseline) compared to CAP prescribing (79% at baseline). Furthermore, we found that 82.5% of patients who received guideline-concordant antibiotic therapy in the ED continued to receive appropriate therapy upon hospital admission. In contrast, only 18.8% of patients who received inappropriate empiric antibiotic therapy in the ED were transitioned to guideline-concordant therapy upon hospital admission. This significant finding highlights the critical importance of initiating appropriate antibiotic therapy up front in the ED.

5. Limitations

There are limitations to our study which must be considered. First, as with all retrospective investigations there is the risk for selection bias as well as the reliance on appropriate documentation. In an attempt to overcome this a randomized sample of all eligible patients was collected from both time periods. Additionally, to minimize the chance of patients' diagnoses being coded improperly, patients were only eligible for inclusion in the study if the ED discharge diagnosis matched the inpatient discharge diagnosis. Furthermore, multivariate logistic

Table 3
Multivariate logistic regression: investigating risk factors for guideline-concordant CAP prescribing.

Variable	Odds ratio (95% CI)	p-Value
EMP present vs absent	4.5 (1.5–14.1)	0.008
Early vs established ASP	2.1 (0.73–6.1)	0.170
Penicillin allergy	0.44 (0.14–1.4)	0.167
White blood cell count > 11 or < 4 cells/μl	0.38 (0.12–1.2)	0.096
Chronic obstructive pulmonary disease	0.55 (0.2–1.5)	0.253
Sepsis diagnosis	0.89 (0.3–2.7)	0.835

Table 4

Multivariate logistic regression: investigating risk factors for guideline-concordant CA-IAI prescribing.

Variable	Odds ratio (95% C.I.)	p-Value
EMP present vs absent	3.3 (1.5–7.3)	0.002
Early vs established ASP	7.5 (3.5–16)	<0.001
Penicillin allergy	2.7 (0.9–7.9)	0.073

regression was performed to control for confounders when assessing for independent risk factors for guideline-concordant prescribing. Second, we examined the ED clinical pharmacists' impact on guideline-concordant antibiotic prescribing for only two disease states, which may over or underestimate their impact on total empiric prescribing. As CAP remains the leading infectious reason for admission, it was chosen as a target for investigation by the study team. The decision to investigate the impact on prescribing for CA-IAI was made as this was a priority target for improved antimicrobial prescribing with the initiation of our ASP team; it was an institutional priority to measure the impact that the EMP and ASP were having on prescribing for this disease state. Third, EMPs were considered present for the hours that they were scheduled to be working. During both study time periods intervention documentation by the EMPs and consultation requests from providers were not required, therefore, it was impossible to know in many cases if the EMP had actually intervened. Additionally, weekend data were excluded as these days are more frequently uncovered by pharmacists due to paid time off or holidays. Overall there are fewer resources available to clinicians during the overnight and weekend hours which may have biased our results in favor of the pharmacist group. Finally, we did not examine the cost associated with the EMP and ASP intervention, therefore, it is difficult to determine the cost effectiveness of this strategy; however, first-line therapy is typically more cost effective and less toxic than alternative agents [10].

6. Conclusion

ED clinical pharmacists are successful extensions of ASPs, effectively stewarding antimicrobial resources without adversely affecting patient outcomes. The presence of an EMP significantly improved guideline-concordant empiric antibiotic prescribing for both CAP and CA-IAI. Guideline-concordant prescribing also significantly increased over time between an early-ASP and established-ASP; the impact of the EMP was demonstrated in both groups. Inpatient antibiotic orders were more likely to be guideline-concordant if appropriate therapy was initiated in the ED.

Acknowledgements

The authors wish to thank Heather Draper, PharmD, BCPS, for her contributions to establishing the ED clinical pharmacy practice at Mercy Health Saint Mary's and Nnaemeka Egwuatu, MD, MPH, for his leadership support of the antimicrobial stewardship program.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- [1] Trinh TD, Klinker KP. Antimicrobial stewardship in the emergency department. *Infect Dis Ther* 2015;4(Suppl. 1):39–50. <https://doi.org/10.1007/s40121-015-0084-8>.
- [2] May L, Cosgrove S, L'Archeveque M, et al. A call to action for antimicrobial stewardship in the emergency department: approaches and strategies. *Ann Emerg Med* 2013;62(1):69–77.e2. <https://doi.org/10.1016/j.annemergmed.2012.09.002>.
- [3] Niska R, Bhuiya F, Xu J. National hospital ambulatory medical care survey: 2007 emergency department summary. *Natl Health Stat Rep* 2010;6(26):1–31.
- [4] Chin MH, Wang LC, Jin L, et al. Appropriateness of medication selection for older persons in an urban academic emergency department. *Acad Emerg Med* 1999;6(12):1232–42.
- [5] Karras D. Antibiotic misuse in the emergency department. *Acad Emerg Med* 2006;13(3):331–3. <https://doi.org/10.1197/j.aem.2005.11.075>.
- [6] Fleming-Dutra KE, Hersh AL, Shapiro DJ, et al. Prevalence of inappropriate antibiotic prescriptions among US ambulatory care visits, 2010–2011. *JAMA* 2016;315(17):1864–73. <https://doi.org/10.1001/jama.2016.4151>.
- [7] Centers for Disease Control and Prevention (CDC). Office-related antibiotic prescribing for persons aged ≤14 years – United States, 1993–1994 to 2007–2008. *MMWR Morb Mortal Wkly Rep* 2011;60(34):1153–6.
- [8] Shapiro DJ, Hicks LA, Pavia AT, Hersh AL. Antibiotic prescribing for adults in ambulatory care in the USA, 2007–09. *J Antimicrob Chemother* 2014;69(1):234–40.
- [9] MacDougall C, Polk RE. Antimicrobial stewardship programs in health care systems. *Clin Microbiol Rev* 2005;18(4):638–56. <https://doi.org/10.1128/CMR.18.4.638-656.2005>.
- [10] Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program: guidelines by the infectious diseases society of America and the society for healthcare epidemiology of America. *Clin Infect Dis* 2016;62(10):e51–77. <https://doi.org/10.1093/cid/ciw118>.
- [11] ASHP. Statement on the pharmacist's role in antimicrobial stewardship and infection prevention and control. *Am J Health Syst Pharm* 2010;67:575–7. <https://doi.org/10.2146/sp100001>.
- [12] Doernberg SB, Abbo LM, Burdette SD, et al. Essential resources and strategies for antibiotic stewardship programs in the acute care setting. *Clin Infect Dis* 2018. <https://doi.org/10.1093/cid/ciy255> [Epub ahead of print].
- [13] Dodds Ashley E, Davis SL, Heil EL, et al. Best care for patients is achieved through multi-disciplinary stewardship. *Clin Infect Dis* 2018. <https://doi.org/10.1093/cid/ciy392> [Epub ahead of print].
- [14] Eppert HD, Reznick AJ. American society of health-system pharmacists. ASHP guidelines on emergency medicine pharmacist services. *Am J Health Syst Pharm* 2011;68(23):e81–95. <https://doi.org/10.2146/sp110020e>.
- [15] Fairbanks RJ, Hildebrand JM, Kolstee KE, Schneider SM, Shah MN. Medical and nursing staff highly value clinical pharmacists in the emergency department. *Emerg Med J* 2007;24(10):716–8. <https://doi.org/10.1136/emj.2006.044313>.
- [16] Coralic Z, Kanzaia HK, Bero L, Stein J. Staff perceptions of an on-site clinical pharmacist program in an academic emergency department after one year. *West J Emerg Med* 2014;15(2):205–10. <https://doi.org/10.5811/westjem.2013.11.18069>.
- [17] American College of Emergency Physicians policy statement. Clinical pharmacist services in the emergency department. Available at <https://www.acep.org/globalassets/new-pdfs/policy-statements/clinical.pharmacist.services.in.ed.pdf>; June 2015. [Accessed June 2, 2018].
- [18] Farmer BM, Hayes BD, Rao R, et al. *J Med Toxicol* 2018;14:114. <https://doi.org/10.1007/s13181-017-0634-4>.
- [19] Dilworth T, Delgado G, Dionne B, et al. SIDP position statement on the role of pharmacist in antibiotic stewardship in the emergency department. Available at: <https://sidp.org/page-1543291/4935842>; July 2017. [Accessed June 2, 2018].
- [20] Faine BA, Mohr N, Dietrich J, et al. Antimicrobial therapy for pneumonia in the emergency department: the impact of clinical pharmacists on appropriateness. *West J Emerg Med* 2017;18(5):856–63. <https://doi.org/10.5811/westjem.2017.5.33901>.
- [21] DeFrates SR, Weant KA, Seamon JP, Shirakbari A, Baker SN. Emergency pharmacist impact on healthcare-associate pneumonia empiric therapy. *J Pharm Pract* 2013;26(2):125–30. <https://doi.org/10.1177/0897190012451933>.
- [22] DeWitt KM, Weiss SJ, Rankin S, Ernst A, Sarangarm P. Impact of an emergency medicine pharmacist on antibiotic dosing adjustment. *Am J Emerg Med* 2016;34(6):980–4. <https://doi.org/10.1016/j.ajem.2016.02.004>.
- [23] Micek ST, Welch EC, Khan J, Perviz M, et al. Resistance to empiric antimicrobial treatment predicts outcome in severe sepsis associated with Gram-negative bacteremia. *J Hosp Med* 2011;6(7):405–10. <https://doi.org/10.1002/jhm.899>.
- [24] Ramphal R. Importance of adequate initial antimicrobial therapy. *Chemotherapy* 2005;51(4):171–6. <https://doi.org/10.1159/000086574>.
- [25] U.S. Department of Health and Human Services Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States, 2013. Available at <http://www.cdc.gov/drugresistance/threat-report-2013>; 2014. [Accessed June 2, 2018].