Multilayer Model of Pharmacy Participation in the Antimicrobial Stewardship Program at a Large Academic Medical Center

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Abstract

Purpose: Leveraging pharmacy personnel resources for the purpose of antimicrobial stewardship program (ASP) operations presents a challenging task. We describe our experience integrating all pharmacists into an ASP, and evaluate the impact on ASP interventions, antimicrobial utilization, rate of selected hospital-onset infections and readmission. **Summary:** During a study period (January 1 to December 31, 2015), a total of 14 552 ASP-related pharmacy interventions were performed (ASP clinical pharmacotherapy specialists [CPS] n = 4025; non-ASP CPS n = 4888; hospital pharmacists n = 5639). Sixty percent of interventions by ASP CPS were initiated utilizing the dedicated ASP phone, and 40% through prospective audit and feedback. Non-ASP CPS performed interventions during bedside rounds (dose adjustment 23%, initiate new or alternative anti-infective 21%, discontinue antibiotic(s) 12%, therapeutic drug monitoring 11%, de-escalation 4%), whereas hospital pharmacists participated at the point of verification (dose adjustment 75%, restricted antibiotic verification 15%, and reporting major drug-drug interactions 4%). The acceptance rate of interventions by providers and clinicians was >90% for all groups. Annual aggregate antimicrobial use decreased by 6.4 days of therapy/1000 patient-days (DOT/1000 PD; P = 1.0). Ceftriaxone use increased by 8.4 DOT/1000 PD (P = .029) without a significant compensatory increase in the use of antipseudomonal agents. Sustained low rates of hospital-onset *Clostridium difficile* (CDI) and carbapenem-resistant *Enterobacteriaceae* (CRE) infections were observed in 2015 compared with the prior year (1.1 and 1.2 cases/1000 PD, 0.2 and 0.1 cases/1000 PD, respectively). Thirty-day readmission rate decreased by 0.6% (P = .019). **Conclusions:** Integration of all pharmacists into ASP activities based on the level of patient care and responsibilities is an effective strategy to expand clinical services provided by ASP.

Keywords

antimicrobial stewardship program, interventions, antimicrobial utilization

Introduction

Antimicrobial stewardship programs (ASPs) have an essential role in improving patient outcomes, reducing antimicrobial adverse events, decreasing antimicrobial resistance, and optimizing resource utilization.^{1–5} The Joint Commission Antimicrobial Stewardship Standard for hospitals mandates establishing an ASP as an organizational priority.⁶ Dedicated medical and pharmacy staff with antimicrobial expertise are critical for ASP success. It is recommended to identify an ASP pharmacist co-leader to partner with a physician leader or physician champion to provide the expertise and accountability needed for high-quality programs.^{6–9} An important role of the ASP pharmacy co-leader is to engage and train

other pharmacy staff in appropriate antibiotic use, thereby enhancing participation in ASP activities.⁷

In 2014, the Centers for Disease Control and Prevention (CDC) published the “CDC Core Elements of Hospital

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Antimicrobial Stewardship Programs” outlining specific pharmacy-driven interventions, such as dosing adjustments, intravenous (IV) to oral antimicrobial switches, and managing antibiotic-related drug interactions.⁸ Recently, Bessesen et al described a novel approach integrating ward pharmacists to perform core ASP interventions at the time of multidisciplinary patient care rounds with their assigned medical teams.⁹ In addition, Chahine et al proposed specific ASP activities to engage pharmacy residents such as extended hours for pharmacist-led prior authorization for restricted antimicrobials.¹⁰ And yet, leveraging pharmacy personnel resources for the purpose of ASP operations presents a challenging task. In this report, we describe our experience establishing a multilayer model of pharmacy participation in ASP to extend comprehensive coverage provided by dedicated full-time ASP clinical pharmacotherapy specialists (CPS).

Methods

Setting

NYU Langone Health Tisch Hospital is a 730-bed tertiary care, academic hospital in New York City. Our pharmacy department provides 24-hour services from a combination of centralized pharmacy and satellite pharmacies. Pharmaceutical services are supported by automated dispensing technology and Epic computerized physician order entry (CPOE) system (Epic Systems Corporation, Verona, Wisconsin), and provided in conjunction with collaborative patient care rounds by CPS in critical care (CC), emergency medicine, infectious diseases (ID), internal medicine, pediatrics, and hematology/oncology. The Department of Pharmacy offers a postgraduate year 1 (PGY1) general pharmacy residency program (4 positions) and PGY2 specialty residency programs in ID (1 position) and CC (1 position).

In December 2008, we initiated a formal ASP for adult patients led by a board-certified ID physician. Our ASP utilizes a combination of preauthorization and prospective audit and feedback (PAF) as core strategies. The ASP developed and implemented facility-specific guidelines to improve antibiotic use for common infections including pneumonia (PNA), sepsis, skin and soft tissue infections, intra-abdominal infections, and urinary tract infections (UTIs). In addition, dosing and monitoring guidelines for aminoglycosides, vancomycin, and β -lactams were established to guide licensed independent providers (LIPs) at the time of ordering, and to assist hospital pharmacists at the point of verification. Although our institution lacks a formal protocol for a pharmacokinetic dosing service, all hospital pharmacists are trained and available to make recommendations for vancomycin and aminoglycoside dosing. Also, both ASP CPS and non-ASP CPS assist with dosing, adjustments, and therapeutic drug monitoring for vancomycin and aminoglycosides. In 2014, rapid microbiologic diagnostic testing (RDT) with polymerase chain reaction (PCR) of blood cultures growing gram-positive cocci (GPC) in pairs

and clusters was introduced. A corresponding workflow where ASP CPS receive electronic real-time notifications 3 times daily to facilitate optimal therapy based on the PCR results was implemented. At the same time, ASP PAF was extended to include medication reconciliation of patients on antiretroviral therapy (ART).

All ASP interventions are directly communicated to the primary team verbally or as a phone call by a member of ASP team as no system for automatic pharmacy interventions is currently established. Prior to July 2014, weekends, holidays, evenings, and nights (“WHEN hours”) constituted a gap in providing comprehensive full-spectrum ASP coverage, because ASP CPS were available only 8 AM to 4 PM during weekdays. Of note, ID fellows were solely responsible for providing approvals for restricted antimicrobials during the weekday hours of 4 PM to 10 PM and on weekends and holidays during the hours of 8 AM to 10 PM.

Establishing Pharmacy Participation in ASP

Preimplementation phase. A stepwise plan outlining a multilayer model to extend pharmacy participation in ASP and provide evening and weekends comprehensive coverage (Figure 1) was developed by the ASP/ID pharmacy clinical manager in collaboration with pharmacy leadership. Based on the proposed model, ASP CPS would continue to perform ASP activities during weekdays; non-ASP CPS would be integrated into ASP to provide high-level activities such as antimicrobial recommendations, approval of restricted antimicrobials, and de-escalation during weekday multidisciplinary bedside patient care rounds; and PGY2 pharmacy residents (ID and CC) would be utilized to extend full on-site ASP coverage to weekends (8 AM–4 PM).¹¹ Hospital pharmacists would be empowered to perform ASP-related interventions at the point of verification of anti-infective orders.

System changes to the CPOE system included customization of Epic iVents (Clinical Interventions) to allow for documentation, tracking, and reporting of ASP interventions based on the level of pharmacist participation in patient care. In addition, ASP CPS developed educational activities for all pharmacists. ASP education consisted of sessions with non-ASP CPS to review ASP guidelines, and sessions with hospital pharmacists to review ASP goals including pharmacy participation, vancomycin and aminoglycosides dosing protocols, allergy documentation, and major anti-infective related drug interactions accompanied by an ID/ASP competency exam at the end of their training. These ID/ASP sessions were integrated into the onboarding process for newly hired hospital pharmacists. For the first 3 months, newly hired non-ASP CPS were required to discuss requests for restricted antibiotics with an ASP CPS before official approval could be provided. An internal pharmacy website was utilized to post all the ASP guidelines, dosing protocols, summaries, and checklists.

Figure 1. Multilayer model of pharmacy participation in antimicrobial stewardship.

Note. ASP = antimicrobial stewardship program; CPS = clinical pharmacotherapy specialist; PAF = prospective audit and feedback; PGY2 = postgraduate year 2.

Implementation phase. In July 2014, a PGY2 clinical weekend program was rolled out to extend pharmacist-driven ASP coverage to 7 days a week.¹¹ The present study took place from January 1 until December 31, 2015. Starting in January 2015, all pharmacists were integrated into ASP at different levels based on their participation in patient care (Figure 1). Pharmacists were responsible for timely documentation of their interventions into the CPOE system. ASP CPS encouraged direct communication via a dedicated ASP phone for any questions related to anti-infectives. In July 2015, additional CPS positions were filled: an ASP CPS for the evening shift extending ASP weekday hours to 9 PM, and 3 full-time non-ASP CPS providing rounding support for 2 additional Internal Medicine teams and the Medical ICU-Step Down Unit (SDU).

Ongoing communication and learning during the study period included reports of interventions disseminated weekly via e-mail to all involved pharmacy staff (ie, ASP CPS, non-ASP CPS, and hospital pharmacists). A case for review and brief “clinical pearls” were included in weekly e-mails to facilitate learning. ASP updates were provided at weekly pharmacy huddles and monthly staff meetings. In addition, reports of ASP interventions were reviewed quarterly and annually at the institutional level via the Antimicrobial Subcommittee of Pharmacy & Therapeutics (P&T) Committee, which was then reported to the institution’s full P&T Committee and ultimately the Medical Board.

Outcomes

During the study period, pharmacy interventions and acceptance rates were documented and used as a process measure. We also evaluated aggregate antimicrobial utilization in 2015 and compared it with the prior year. Outcome measures included rate of hospital-onset *Clostridium difficile* infection

(CDI), rate of hospital-onset infections caused by carbapenem-resistant *Enterobacteriaceae* (CRE), percent of *Enterobacteriaceae* nonsusceptible to ceftriaxone, and 30-day readmission rate. These outcomes were also compared between the study period and the prior year.

Definitions

Aggregate antimicrobial use was measured in days of therapy/1000 patient-days (DOT/1000 PD) according to CDC standards.^{12,13} Rates of CDI and CRE were calculated using data generated by our Infection Prevention and Control (IPC) department that is reported to CDC using National Health and Safety Network (NHSN) definitions. Data from yearly antibiograms generated by our microbiology laboratory were used to calculate percent of *Enterobacteriaceae* nonsusceptible to ceftriaxone. A pharmacy database of administered antimicrobials was used to calculate 30-day readmission rate for all patients who received at least 1 dose of antimicrobials during hospital stay.

Statistical Analysis

The independent-samples Mann-Whitney *U* test and chi-square test were used to compare median quarterly DOT/1000 PD and 30-day rate of readmission, respectively. *P* value $\leq .05$ denoted statistical significance. All analyses were performed using SPSS version 23 (IBM Corp, Armonk, New York).

Results

Pharmacy Interventions

A total of 14 552 ASP-related pharmacy interventions were performed during the study period (ASP CPS *n* = 4025;

non-ASP CPS $n = 4888$; hospital pharmacists $n = 5639$). With the increase in staffing and extended ASP hours, the total number of interventions performed by ASP CPS and non-ASP CPS in quarters 1 and 2 as compared with quarters 3 and 4 increased by 19.7% ($n = 441$) and 2.3% ($n = 58$), respectively. As compared with 2014, there was an increase in the total number of interventions for all groups (34% for ASP CPS, 26% by non-ASP CPS, 39% by hospital pharmacists). The type of interventions performed by ASP CPS, non-ASP CPS, and hospital pharmacists (Table 1) represented different levels of participation and supports our multilayer model. Of note, interventions performed by the pharmacy residents were included in all calculations.

For ASP CPS, 60% of interventions were through incoming calls to a dedicated ASP phone, and 40% through PAF. Of note, only 34% of calls were requests for approval of restricted antimicrobials. The overall approval rate for restricted antimicrobials by the ASP team was 70%. The approval rate was 68% during weekdays for 3 ASP CPS as compared with 77% during weekends for PGY2 ID and CC residents. Among the remaining general ASP calls, the majority of calls were for antimicrobial recommendations and/or culture and susceptibility review (51%). The most common antimicrobial agents targeted during ASP phone interactions were vancomycin (29%), piperacillin-tazobactam (PTZ, 14%), fluoroquinolones (13%), cefepime (12%), ceftriaxone (12%), and meropenem (5%). Among PAF interventions documented by the ASP team (40% of total ASP team interventions), the most common included pharmacokinetic (PK)/pharmacodynamic (PD) dosing and monitoring for aminoglycosides and/or vancomycin (21%), antibiotic dose adjustment (18%), discontinuation of unnecessary therapy (13%), recommendation for alternative therapy including bug-drug mismatches (7%), and de-escalation (6%). Review of positive blood culture reports after RDT resulted in discontinuation of unnecessary antibiotics in 14% of cases and de-escalation to optimal therapy in 24% of cases. The most common antimicrobial agents that required interventions were vancomycin (41%), cefepime (11%), PTZ (7%), meropenem (7%), and fluoroquinolones (5%).

Non-ASP CPS served as an extension of our ASP by delivering high-level ASP interventions at the patient bedside and providing ASP education for physicians and LIPs in real time. ASP-related interventions performed by the 10 non-ASP CPS included dosing regimen adjustment (23%), discontinuation of antibiotic(s) (12%), initiation of alternative antibiotic (ie, bug-drug mismatch, 10%), initiation of new anti-infective (11%), therapeutic drug monitoring (11%), and de-escalation (4%). Hospital pharmacists acted as gatekeepers at the point of anti-infective order verification, ensuring appropriate dosing and compliance with hospital policies. Common ASP interventions performed by 65 hospital pharmacists were dosing adjustments (75%), adjusting duration of overnight restricted antibiotic orders to 24 h (6%), reporting

Table 1. Pharmacy Interventions at Different Levels Based on Participation in Patient Care (Study Period—Year 2015).^a

Intervention type or recommendation	No. of interventions (%)
ASP team^{a,b}	
Phone calls handled by ASP	
Calls for approval of restricted antibiotics	
Requests	827 (34)
Approved	580 (70)
No change in therapy recommended	340 (59)
Change dose/route	148 (25)
Duration of therapy recommended	57 (10)
Recommended culture	35 (6)
Not approved	247 (30)
Alternative therapy	229 (93)
No therapy needed	18 (7)
General calls	1592 (66)
Antimicrobial recommendation and/or culture and susceptibilities review	816 (51)
Call from staff pharmacist	494 (31)
PK/PD dosing	192 (12)
Recommend ID consult	18 (1)
Nonformulary request	16 (1)
Follow-up	12 (1)
Other	44 (3)
Total number of phone calls	2419
Average number of calls per day	7
Prospective audit and feedback	
PK/PD dosing for vancomycin and aminoglycosides	339 (21)
Dose adjustment	293 (18)
Discontinue unnecessary therapy	210 (13)
Rapid blood culture review	152 (9)
De-escalate	36 (24)
Discontinue therapy	21 (14)
Other	95 (62)
Recommend alternative therapy (ie, drug-bug mismatch)	119 (7)
De-escalate/narrow therapy	100 (6)
IV to PO switch	70 (5)
Recommend duration of therapy	71 (5)
ART reconciliation	78 (5)
Recommend ID consult	20 (1)
Drug interactions	15 (1)
Recommend culture	8 (<1)
Other	131 (8)
Total	1606
Accepted	1564 (97)
Average interventions per day	4.5
Non-ASP CPS interventions during multidisciplinary patient care bedside rounds^{a,b}	
Dosing regimen adjustment ^c	1135 (23)
Vancomycin	357 (31)

(continued)

Table 1. (continued)

Intervention type or recommendation	No. of interventions (%)
Cefepime	150 (13)
Meropenem	111 (10)
Piperacillin-tazobactam	79 (7)
Discontinue antibiotic ^c	582 (12)
Vancomycin	177 (30)
Azithromycin	98 (17)
Metronidazole	57 (10)
Initiate new anti-infective	550 (11)
Initiate alternative anti-infective (ie, drug-bug mismatch)	480 (10)
De-escalate/narrow therapy	188 (4)
Therapeutic drug monitoring ^c	524 (11)
Vancomycin	392 (75)
Aminoglycosides	47 (9)
IV to PO switch	307 (6)
Other	1122 (23)
Total	4888
Accepted	4839 (99)
Average interventions per day	13
Hospital pharmacists interventions at the point of verification	
Dosing regimen adjustment ^c	4229 (75)
Vancomycin	1388 (33)
Cefepime	651 (15)
Piperacillin-tazobactam	301 (7)
Aminoglycosides	212 (5)
Fluoroquinolones	145 (3)
Restricted antibiotic—approval clarification	523 (9)
Restricted antibiotic—overnight 9 PM-8 AM verification (24 h only)	335 (6)
Drug interaction prevention: major	209 (4)
Allergic reaction prevention: major	195 (3)
Vancomycin drug level reviewed/supratherapeutic level	96 (2)
IV to PO switch	52 (1)
Total	5639
Accepted	5131 (91)
Average interventions per day	15

Note. ASP = antimicrobial stewardship program; IV = intravenous; PO = oral; ART = antiretroviral therapy; CPS = clinical pharmacotherapy specialists.

^aInterventions for adult services only included.

^bInterventions performed by pharmacy residents during weekends and weekdays included in the count.

^cMost common antibiotics related to intervention.

major drug-drug interactions (4%), and clarification of severe allergy (3%). The acceptance rate of pharmacy interventions by providers and clinicians was high: 97% for ASP CPS, 99% for non-ASP CPS, and 91% for hospital pharmacists.

Antimicrobial Utilization

Annual aggregate antimicrobial use during the study period decreased by 6.4 DOT/1000 PD from the preceding 12-month period ($P = 1.0$; Table 2). Ceftriaxone use increased by 8.4 DOT/1000 PD ($P = .029$) without a significant compensatory change in the use of antipseudomonal agents. Of note, combined use of PTZ and cefepime decreased by 5.4 DOT/1000 PD ($P = .114$) during the study period. Fluoroquinolone use remained low and decreased by 0.6 DOT/1000 PD ($P = 1.0$). Carbapenem use increased by 1.2 DOT/1000 PD ($P = .686$). In line with our new ASP initiative incorporating RDT of positive blood cultures, there was a corresponding increase of 2.6 DOT/1000 PD in use of antistaphylococcal penicillins for methicillin-susceptible *Staphylococcus aureus* (MSSA) bacteremia ($P = .029$). Use of antibiotics with activity against methicillin-resistant *Staphylococcus aureus* (MRSA) increased during the study period as compared with the previous 12 months ($P = .886$). Although vancomycin and linezolid use increased by 4.8 DOT/1000 PD ($P = .486$) and 1.7 DOT/1000 PD ($P = .686$); daptomycin and ceftaroline use decreased by 2.1 DOT/1000 PD ($P = .2$) and 0.8 DOT/1000 PD ($P = .2$), respectively. Micafungin use also decreased by 1.0 DOT/1000 PD ($P = 1.0$). Overall, the shift in antimicrobial utilization aligned with institutional guidelines and ASP initiatives.

Outcome Measures

The rate of hospital-onset CDI decreased slightly from 1.2 to 1.1 cases/1000 PD (ie, 122 CDI cases/108 772 PD during the study period and 128 CDI cases/103 650 PD in 2014). The observed lower CDI rate was likely due to multifactorial initiatives implemented by our IPC department, including hospital-wide campaigns to improve hand-hygiene, cleaning of frequently touched surfaces, and oral vancomycin suppressive therapy for patients with prior episodes of CDI. Establishing pharmacy participation in ASP and extending ASP hours may have contributed to maintaining CDI rates low as well. CRE rates remained low, with hospital-onset CRE rate of 0.2 cases/1000 PD (18 cases/103 650 PD) and 0.1 cases/1000 PD (16 cases/108 772 PD) in 2015 and 2014, respectively. In addition, there was a 2% reduction in *Enterobacteriaceae* nonsusceptible to ceftriaxone in 2015 compared with 2014 (17% [207 of 1231] and 15% [170 of 1152], respectively). The 30-day readmission rate for patients who received at least 1 dose of antibiotics during their hospital stay decreased by 0.6% (from 7.2% [1259/17 354] in 2014 to 6.6% [1181/17 900] in 2015, $P = .019$).

Discussion

We describe a multilayer model that we implemented to leverage pharmacy personnel resources for the purposes of ASP. Integration of non-ASP CPS to perform ASP activities

Table 2. Comparison of Antimicrobial Utilization in Days of Therapy/1000 Patient-Days (DOT/1000 PD).^a

	Prior 12 months (year 2014)	Study period (year 2015)	Absolute change	P value ^b
Aggregate use ^c	759.2 (728.6-795.3)	752.8 (749.3-799.6)	↓6.4	1.0
Piperacillin-tazobactam and cefepime combined	126.3 (124.7-127.8)	120.9 (114.6-125.7)	↓5.4	.114
Antibiotics with MRSA coverage combined (vancomycin, daptomycin, linezolid, ceftaroline)	139.2 (131.1-147.0)	143.6 (135.1-147.0)	↓4.4	.886
Vancomycin intravenous	114.1 (109.0-123.0)	118.9 (115.8-124.3)	↑4.8	.486
Daptomycin	8.0 (6.7-9.0)	5.9 (4.2-7.9)	↓2.1	.2
Linezolid	13.2 (9.9-18.5)	14.9 (12.5-17.3)	↑1.7	.686
Ceftaroline	2.0 (1.5-2.5)	1.2 (0.9-2.2)	↓0.8	.2
Ceftriaxone	40.5 (37.0-42.0)	48.9 (46.9-51.6)	↑8.4	.029
Carbapenems (imipenem, meropenem, ertapenem) combined	37.9 (31.3-40.9)	39.1 (35.0-43.8)	↑1.2	.686
Meropenem	35.1 (28.6-38.0)	35.8 (31.5-40.1)	↑0.7	.686
Fluoroquinolones (ciprofloxacin and levofloxacin) combined	26.4 (24.1-31.8)	25.8 (23.8-29.3)	↓0.6	1.0
Oxacillin and nafcillin combined	4.4 (3.8-4.7)	7.0 (5.5-7.4)	↑2.6	.029
Micafungin	11.9 (9.3-14.9)	10.9 (9.5-15.5)	↓1	1.0

Note. MRSA = methicillin-resistant *Staphylococcus aureus*.

^aAll values are measured in DOT/1000 PD and presented as median (interquartile range).

^bMedian of quarterly antimicrobial use for study period and a year prior was compared. P values were determined by independent-samples Mann-Whitney U test.

^cAll hospital adult patients units excluding operation room and emergency department observation included; all antimicrobials and antifungals combined, antivirals not included.

and their expansion to all hospitalist services in internal medicine and to the medical SDU allowed AS to be performed at the bedside for services with a high proportion of patients on antimicrobials. As a collateral benefit, participation of non-ASP CPS also permitted ASP CPS to focus on services that cannot be provided by the rounding CPS and to ensure a manageable load of ASP phone calls and PAF interventions in large academic medical center with daily bed-census in 500 to 700 range. A similar approach integrating rounding pharmacists into ASP was recently described by Carreno et al and Bessesen et al.^{9,14} Furthermore, extending ASP CPS coverage to evenings and weekends provided workflows and services similar to what the day shift ASP CPS team was already providing. ASP weekend coverage by the PGY2 residents resulted in uniformity of service provided, permitted patient handoffs to the weekday ASP team, and promoted continuity of care. Continuous communication, support, and education through weekly reports of interventions and teaching cases via e-mail, weekly participation at pharmacy department huddles, and monthly updates at staff meetings were well received from our hospital pharmacists. This helped to maintain a collaborative working environment between hospital pharmacists and CPS and engaged hospital pharmacists in ASP at the point of order verification. Overall, we observed improved communication between ASP CPS and hospital pharmacists. This is evident by the number of calls made by hospital pharmacists (n = 494) to ASP CPS to address their questions related to antimicrobial verification.

As previously described in the literature, integration of a CPOE system is critical for ASP success.¹⁵ Implementation of a structured documentation system prior to the study period warranted timely documentation of interventions into the CPOE system by all pharmacists, which was used as a process measure of pharmacy participation. In addition, ongoing education related to documentation and reporting of interventions performed by all pharmacists has allowed the ongoing tracking of pharmacy participation.

Although the only significant outcome measure documented in our study was 30-day readmission rate, reported trends of antimicrobial utilization and rates of hospital-onset CDI and CRE were consistent with ASP guidelines and initiatives. It is also important to emphasize that ASP interventions and ASP impact should be viewed as a small component of bigger hospital-wide and IPC initiatives to decrease length of stay, improve hand-hygiene and cleaning, and provide evidence-based and value-based medicine.

Our study has a number of limitations, including the retrospective single-center design, short study period (i.e., 1 year), absence of well-defined CDC metric for 30-day readmission due to infection,¹⁶ dependence on the accuracy of documentation to measure the acceptance rate for pharmacy interventions, and possible discrepancies in comparison of pharmacy participation in ASP between years due to the limited training and lack of tracking of communication between pharmacists and ASP CPS in 2014. In the subsequent year of 2016, we expanded ASP by adopting new interventions such as syndrome-specific reviews for CDI,

UTIs, PNA, and bacteremia, as well as improved the CPOE system's flags and dashboard to effectively identify targets of potential interventions. We continue to work on improving ASP CPS communication with hospital pharmacists and non-ASP CPS and integrating all pharmacists into additional ASP activities.

Conclusion

ASP-related services were expanded at our institution by increasing ASP CPS staffing and coverage, integrating non-ASP CPS at the time of multidisciplinary bedside patient care rounds, involving hospital pharmacists at the point of verification, and designating PGY2 pharmacy residents to provide on-site ASP weekend coverage. An increase in ceftriaxone use, a narrower spectrum antibiotic, without compensatory significant increase in broader spectrum antimicrobials; a sustained low rate of hospital-onset CDI and CRE; and reduction in 30-day readmission rate were observed. Overall, establishing multilayered pharmacy participation in ASP is an effective strategy to extend coverage provided by ASP CPS.

Authors' Note

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References

1. Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program: guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis*. 2016;62(10):e51-e77.
2. Davey P, Brown E, Charani E, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. *Cochrane Database Syst Rev*. 2017;2:CD003543.
3. DiazGranados CA. Prospective audit for antimicrobial stewardship in intensive care: impact on resistance and clinical outcomes. *Am J Infect Control*. 2012;40(6):526-529.
4. Brumley PE, Malani AN, Kabara JJ, Pisani J, Collins CD. Effect of an antimicrobial stewardship bundle for patients with *Clostridium difficile* infection. *J Antimicrob Chemother*. 2016;71(3):836-840.
5. Elligsen M, Walker SA, Pinto R, et al. Audit and feedback to reduce broad-spectrum antibiotic use among intensive care unit patients: a controlled interrupted time series analysis. *Infect Control Hosp Epidemiol*. 2012;33(4):354-361.
6. New Antimicrobial Stewardship Standard. https://www.joint-commission.org/assets/1/6/New_Antimicrobial_Stewardship_Standard.pdf. Accessed February 14, 2017.
7. National quality partners playbook: antibiotic stewardship in acute care. http://www.qualityforum.org/Publications/2016/05/National_Quality_Partners_Playbook_Antibiotic_Stewardship_in_Acute_Care.aspx. Accessed February 14, 2017.
8. Centers for Disease Control and Prevention (CDC). Core elements of hospital antibiotic stewardship programs. <https://www.cdc.gov/getsmart/healthcare/implementation/core-elements.html>. Accessed February 14, 2017.
9. Bessesen MT, Ma A, Clegg D. Antimicrobial stewardship programs: comparison of a program with infectious diseases pharmacist support to a program with a geographic pharmacist staffing model. *Hosp Pharm*. 2015;50:477-483.
10. Chahine EB, El-Lababidi RM, Sourial M. Engaging pharmacy students, residents, and fellows in antimicrobial stewardship. *J Pharm Pract*. 2015;28(6):585-591.
11. Siegfried J, Merchan C, Scipione MR, Papadopoulos J, Dabestani A, Dubrovskaya Y. Role of postgraduate year 2 pharmacy residents in providing weekend antimicrobial stewardship coverage in an academic medical center. *Am J Health Syst Pharm*. 2017;74(6):417-423.
12. Polk RE, Fox C, Mahoney A, Letcavage J, MacDougall C. Measurement of adult antibacterial drug use in 130 US hospitals: comparison of defined daily dose and days of therapy. *Clin Infect Dis*. 2007;44(5):664-670.
13. Ibrahim OM, Polk RE. Antimicrobial use metrics and benchmarking to improve stewardship outcomes: methodology, opportunities, and challenges. *Infect Dis Clin North Am*. 2014;28(2):195-214.
14. Carreno JJ, Kenney RM, Bloome M, et al. Evaluation of pharmacy generalists performing antimicrobial stewardship services. *Am J Health Syst Pharm*. 2015;72(15):1298-1303.
15. Forrest GN, Van Schooneveld TC, Kullar R, Schulz LT, Duong P, Postelnick M. Use of electronic health records and clinical decision support systems for antimicrobial stewardship. *Clin Infect Dis*. 2014;59(suppl 3):S122-S133.
16. Moehring RW, Anderson DJ, Cochran RL, et al. Expert consensus on metrics to assess the impact of patient-level antimicrobial stewardship interventions in acute-care settings. *Clin Infect Dis*. 2017;64(3):377-383.