RESEARCH ARTICLE

Implementing an Inpatient Pediatric Prospective Audit and Feedback Antimicrobial Stewardship Program Within a Larger Medical Center

Jennifer Lighter-Fisher, MD,[a,b] Sonya Desai, Pharm D, BCPS, BCPPS,[c] Anna Stachel, MPH, CIC,[a] Vinh Philip Pham, MD, PhD,[a,c] Liana Klejmont, Pharm D, BCPS, BCPPS,[b] Yanina Dubrovskaya, Pharm D, BCPS[c]

ABSTRACT

BACKGROUND: Pediatric antimicrobial stewardship programs (ASPs) within larger institutions have unique opportunities to develop programs specialized to the needs of the pediatric program. In January 2013, our institution established a formalized pediatric ASP utilizing the prospective audit and feedback process. In an effort to standardize therapy and improve quality of care, members of the ASP developed evidence-based guidelines for management of common inpatient pediatric infections. ASP members met periodically with faculty and house staff to discuss guidelines and ways to improve prescribing.

METHODS: Provider adherence with clinical inpatient practice guidelines, frequency of interventions suggested by ASP, and acceptance of interventions by providers were elements used to measure process change. We measured outcome data by analyzing antimicrobial utilization (defined as days of therapy) and length of therapy.

RESULTS: Over a period of 2 years, institutional ASP guidelines were applicable to nearly half (44%) of all antimicrobial orders. Interventions were performed on 30% of all antimicrobial orders, of which 89% were accepted. Total antimicrobial days of therapy and length of therapy decreased significantly when comparing pre- and post-ASP. Overall, the susceptibility profiles of common bacterial pathogens to antibiotics remained stable.

CONCLUSIONS: Pediatric ASPs within larger institutions have opportunities to create programs specific to the needs of the population they serve. We observed high rates of adherence by providers and a subsequent reduction in antibiotic utilization when implementing an audit feedback-based process.

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Address correspondence to Jennifer Lighter-Fisher, MD, Department of Pediatrics, NYU Langone Medical Center, 550 First Ave, New York, NY 10016. E-mail: jennifer.lighter@nyumc.org

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[a]Infection Prevention and Control, [b]Division of Pediatric Infectious Diseases and Immunology, Department of Pediatrics, and [c]Pharmacy Department, New York University Langone Medical Center, New York, New York

Antimicrobial use in hospitalized children is common. In 2008, 60% of the children discharged from 40 freestanding US children's hospitals received at least 1 antimicrobial agent during their hospitalization, including >90% of patients who had surgery, underwent central venous catheter placement, had prolonged ventilation, or remained in the hospital for >14 days.[1] However, 20% to 50% of all antibiotics prescribed in hospitals located in the United States are either unnecessary or inappropriate.[2–6] Antimicrobial stewardship programs (ASPs) have demonstrated a positive impact on optimizing effective and safe antimicrobial utilization[7–10] and may delay development of antimicrobial resistance.

In 2007 and 2016, the Infectious Disease Society of America and the Society for Healthcare Epidemiology of America published guidelines for initiating ASPs in acute care hospitals.[7,11] The majority of recommendations reflected studies and interventions in adults. Recommended core strategies include formulary restriction with preauthorization as well as prospective audit and feedback; however, questions remain regarding the optimal process to yield improved patient outcomes. For several years at our institution we had a formal ASP based on restricted antimicrobial agents for adult medicine patients only. Unrelated to this medicine ASP, we also had an informal pediatric infectious diseases (IDs), fellow-led, restricted antimicrobial process in which ~25 antimicrobial agents required preauthorization. This typically involved contacting the ID fellow, who briefly discussed the clinical context with the provider and then communicated with the pharmacy, for release of the antimicrobial. The process was generally not documented in the health record, and further review of antimicrobial agents was not conducted unless a pediatric ID consultation was requested.

The pediatric ID fellow-led restricted program was suboptimal, because there was no strategic planning or education directed toward reducing overall antibiotic use or reducing unwarranted use of broad spectrum antimicrobial agents. Antibiotics were often not optimized and there was no system in place to monitor trends of antimicrobial usage and bacterial susceptibility or to improve prescribing. Likewise, there was no standardized management of common infections for children admitted to our medical center.

In this evaluation, we report on the effect of implementing a hospital pediatric ASP program within a larger medical center. We measure provider process change by the frequency of accepted ASP recommendations and adherence with local clinical practice guidelines. Additionally, we compare outcome data between the time periods of simple antimicrobial restriction versus the expanded prospective audit and feedback system.

METHODS

Study Design and Setting

Children's Services at NYU Langone Medical Center consists of 4 inpatient units totaling 109 beds within a larger 1069-bed tertiary care academic medical center. There are 33 beds in our general pediatric and oncology ward and a total of 48 ICU beds (13 PICU beds, 29 NICU beds, and 6 critical cardiovascular care unit beds). In January 2013, we initiated a formal pediatric ASP focused on inpatients, led by a board-certified pediatric ID physician and epidemiologist, as well as 2 pediatric clinical doctors of pharmacy, who specialize in pharmacology in neonatology, and in pharmacology in children treated for cancer, respectively. Our program used a prospective audit and feedback system on 20 antimicrobial agents with 6 remaining restricted (Table 1). The 6 restricted antimicrobial agents required a pediatric ID consultation for usage.

Audited antimicrobial orders were conducted 48 to 72 hours after initial prescription when laboratory and radiologic data were available. One of the members of the pediatric ASP program would review a real-time report on our electronic medical record (EMR), (Epic, Verona, WI). Audit information was entered into an electronic database along with the associated indication for the antimicrobial, adherence to clinical practice guidelines when applicable, type of recommendation if one occurred, and acceptance or deferral of the recommendation by the primary physician team. Interventions suggested by the pediatric ASP included the following: discontinuation of therapy-based microbiologic results, optimization of therapy (broadening or narrowing antibiotic coverage, consideration of an alternative antimicrobial, adverse event monitoring recommendations, antibiotic changes due to microbiologic results or toxicities, and formulary recommendations), modification of therapy (dose adjustment and conversion of parenteral to oral therapy), and suggesting a full billable pediatric ID consultation. When we made multiple interventions on a given antimicrobial (eg, simultaneously optimizing therapy and suggesting a pediatric ID consult), we usually categorized the intervention under therapy optimization. Recommendations were suggested to the house staff and faculty managing the patient via a friendly e-mail or phone call by a member of the pediatric ASP. All audits were reviewed at 24 hours to identify if recommendations were followed. Because of the administrative role of ASP, recommendations were not documented in the EMR.

Over the course of the first 2 years of the program, we developed clinical practice guidelines based on the most common IDs treated at our institution, of which there are no national pediatric guidelines. These included guidelines for the workup and management of the following: acute hematogenous osteomyelitis, acute arthritis, sepsis, prophylaxis of neutropenic patients, fever and neutropenia, pleural empyema, *Clostridium difficile* infections, intraoperative antibiotics for high risk surgeries, and treating and decolonizing methicillin-resistant *Staphylococcus aureus* (MRSA) infections. Additionally, antibiotic dosing and monitoring guidelines were developed for the more commonly used antimicrobial agents that were often misdosed: vancomycin, aminoglycosides, and piperacillin-tazobactam extended infusion. The process of developing institutional ASP guidelines combined

TABLE 1 ASP-Targeted Antimicrobial Agents Requiring ASP Review in the Prospective Audit Period and Restricted Antimicrobial Agents Requiring a Pediatric Infectious Diseases Consult

	Antibacterial	Antiviral	Antifungal
ASP reviews at 48–72 h			
	Amikacin	Ganciclovir	Ambisome
	Cefepime	Valganiciclovir	Amphotericin B Lipid Complex
	Ceftazidine		Caspofungin
	Ciprofloxacin		Micafungin
	Clindamycin		
	Ertapenem		
	Levofloxacin		
	Meropenem		
	Piperacillin-tazobactam		
	Rifampin		
	Tobramycin		
	Vancomycin		
Restricted and pediatric ID consulted if ordered			
	Daptomycin		Flucytosine
	Polymixin B Sulfate		Voriconazole
	Linezolid		
	Tigecycline		

recent Infectious Disease Society of America or National Comprehensive Cancer Network guidelines, recent evidence since publication of national guidelines, and input from the pharmacy department, pediatric ID faculty, and faculty from other specialties (eg, oncology, orthopedics, etc). Institutional ASP and pharmacy and therapeutic committees then approved each guideline before its release. Cycles of education and re-education were employed for implementation. Finally, we developed antibiograms for each pediatric inpatient unit including subspecialty populations such as cystic fibrosis and gravid women who were group B *Streptococcus* positive.

Measuring Acceptance of Pediatric ASP Interventions and Study Outcomes

Members of the pediatric ASP performed a retrospective cohort study of all antimicrobial orders placed for all patients admitted to any of the pediatric units from January 2013 through December 2015. We collected data from 2 years before (January 2010–December 2011) and 2 years after (January 2014–December 2015) implementation of a formal pediatric ASP. We omitted analysis of years 2012 and 2013 because of the closure of inpatient units (secondary to events related to Hurricane Sandy, as well as the introduction of a new electronic health record system). Additionally, the time necessary for developing guidelines, providing education, and implementing the guidelines may have affected our findings in 2013.

We measured acceptance of pediatric ASP interventions by analyzing any changes in prescription of antimicrobial agents made within 24 hours of ASP recommendations. Rates of adherence with clinical practice guidelines were calculated. We assessed outcomes as potential markers of the pediatric ASP's effect on improving patient safety. Selected outcomes included bacterial resistance patterns provided by the clinical microbiology laboratory. We used unique culture results for each patient from children admitted to the medial center during the pre- and post-ASP periods. We analyzed billing data from new inpatient pediatric IDs consults to calculate their yearly frequency.

We measured antimicrobial utilization in days of therapy (DOTs) per 1000 patient days (PDs).[12,13] One DOT represents the administration of a single agent on a given day regardless of the number of doses administered or dosage strength.[12] DOTs were extracted on the basis of administered intravenous and oral antibiotics and antifungal agents to all inpatient units, excluding the emergency department. Antivirals were not included. Topical, otic, and inhaled routes were not included. An additional metric, length of therapy (LOT) was used to evaluate the duration of therapy irrespective of the number of antimicrobial agents administered each day.[13] We used LOT per 1000 PDs to provide an aggregate-level estimate of the average duration of therapy among patients who received antibiotics. We calculated LOT per admission by summing the total LOT and dividing by number of admissions when a patient received antimicrobial therapy for the selected time period.[13] We used a system developed in-house (Access Database [Microsoft Corp, Redmond, WA] and automated queries) to calculate DOTs, LOT, PDs, and admissions among the patients on antibiotics and antifungal agents. PD data were extracted by using Crystal Reports (SAP SE, Walldorf, Germany). We obtained admission and discharge data from the EMR. The accuracy of the system was tested previously by comparison with United Healthcare Consortium.[13–15]

Data Analysis

The independent samples Mann–Whitney *U* Test was used to compare median monthly DOTs per 1000 PDs and median monthly LOT per 1000 PDs and LOT per admission in the pre- and post-ASP periods. A 2-sided *P* value of $\leq$.05 denoted statistical significance. All analyses were performed using IBM SPSS Statistics, version 20.0 (IBM Corp, Armonk, NY).

RESULTS

In the 2 years post-ASP period, we reviewed a total of 1211 antimicrobial orders. Interventions predominantly were made on young children, with 40% occurring in infants (<12 months), 30% in children 1 to 5 years of age, 9% in children 6 to 12 years of age and 21% in children over 12 years of age. During this time period, 73% of all pediatric admissions were children <12 months of age; 9% of admissions

occurred in each of the other 3 age groups: 1 to 5 years, 6 to 12 years, and >12 years. Antibiotic and clinical practice guidelines developed by ASP were immediately relevant to the prescribing patterns of the providers, and by 2014 the institutional ASP guidelines were applicable to nearly half (44%) of all antimicrobial orders. Among the orders that were directly applicable to the documented ASP clinical and antibiotic guidelines, we observed an 88% adherence rate to the suggestions (eg, selected antimicrobial, dosage, conversion to oral therapy, etc) in the standing ASP Clinical Guidelines.

Pediatric ASP interventions were performed on 30% ($n = 362$) of the total orders over the 2 years. The most common intervention was optimization, which comprised 71% of all interventions. Other interventions included discontinuing therapy (15%), modification of therapy (9%), and recommending an official pediatric ID consult (5%).

Among the interventions made by the pediatric ASP team, the antimicrobial agents with the highest percentage of intervention per prescription were piperacillin-tazobactam (44%), vancomycin (42%), cefepime (37%), and meropenem (23%). The most common piperacillin-tazobactam recommendation was to use an extended infusion protocol to maximize time-dependent bacterial killing.[16–19] We often made the suggestion to discontinue therapy for vancomycin when cultures were revealed to be negative during the 48- to 72-hour feedback period. Another common vancomycin recommendation was dose modification, most commonly to increase the dose or frequency because of subtherapeutic troughs. Dose modifications were also the most common intervention with cefepime and meropenem. Half of the meropenem interventions were suggestions for a full pediatric ID consultation.

We observed an increase in hospital pediatric ID consultations when comparing pre- and post-implementation of the formal pediatric ASP. In 2010 and 2011 there were a total of 340 pediatric ID consults among 38 247 inpatient days, which was a rate of 0.89 consults per 100 PDs. In contrast, in 2014 and 2015 there were 482 pediatric ID consultations among the 37 955 inpatient days, a rate of 1.27 per 100 PDs (net change +33%; $P < .0001$).

Among the 362 pediatric ASP interventions, 322 (89%) were accepted, and the antimicrobial orders were modified per the suggestions of the pediatric ASP. The most common reason for not accepting an intervention was due to preferential continuation of antibiotics for suspected sepsis. Among these 40 cases, 30 (75%) were in children in the ICU and 8 were in children being treated for febrile neutropenia.

Antimicrobial utilization significantly decreased after implementation of the formal pediatric ASP. Overall aggregate median monthly antimicrobial use (including antimicrobial agents and antifungal agents) decreased from 803 (interquartile range [IQR] 766–880) DOTs per 1000 PDs in 2010–2011 to 761 (IQR 690–806) DOTs per 1000 PDs from 2014–2015 ($P = .031$). ASP-targeted antibiotic use trended toward decrease from monthly median 308 (IQR 261–335) DOTs per 1000 PDs in 2010–2011 to 260 (IQR 252–308) DOTs per 1000 PDs in 2014–2015 ($P = .08$). The median monthly LOT per 1000 PDs significantly decreased from 481 (IQR 447–512) to 431 (IQR 401–500) pre- and post-implementation of formal pediatric ASP, respectively ($P = .038$). The median monthly LOT per admission was 5.2 (IQR 4.7–5.7) and 4.8 (IQR 4.2–5.2) pre- and post-implementation of formal pediatric ASP, respectively ($P = .007$).

Regarding specific antimicrobial agents (Table 2), we observed a significant ($P < .05$) decrease in audited broad-spectrum antibiotic use, specifically in those targeting Gram-negative bacteria (including *Pseudomonas*): piperacillin-tazobactam, ceftazidime, fluroquinolones, and the aminoglycosides. This coincided with a significant increase in ceftriaxone usage. Although ceftriaxone is a third-generation cephalosporin and has somewhat of a broad coverage, it is considered a narrower agent than cefepime, piperacillin-tazobactam, and ceftazidime. After a formal ASP program was introduced, we also observed a significant decrease in vancomycin usage ($P = .015$) and other antibiotics used for empirical coverage of sepsis: ampicillin, gentamicin, cefepime, and cefotaxime. There was an increase in the orally used antibiotic linezolid ($P = .005$), although bactrim and ciprofloaxin usage essentially remained unchanged. A decrease in anti-staphylococcal penicillins usage (nafcillin and oxacillin) correlated with an increase in community-onset methicillin-resistant *Staphylococcus aureus* (CO-MRSA) infections treated at our hospital. We observed a twofold increase in community-onset MRSA skin and soft tissue infections pre- and post-ASP (36 in 2010–2011 and 71 in 2014–2015). Lastly, we observed a significant increase in cefoxitin usage, which was suspected to be secondary to pediatric ASP intraoperative antibiotic guidelines.

Micafungin became the antifungal drug of choice for prophylaxis in the children receiving chemotherapy with vinca alkaloids. We observed a significant decrease in overall antifungal use, and the number of invasive fungemias in children significantly decreased from 18 (rate of 0.47 per 1000 PDs) to 3 (rate of 0.08 per 1000 PDs), respectively ($P < .005$), pre- and post-implementation of a formal pediatric ASP.

We noted overall stability and some decrease in antimicrobial resistance among Gram-negative organisms (Table 3). Specifically, we compared susceptibility patterns for *Acinetobacter baumannii, Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa*, and *Enterobacter cloacae* pre- and post-implementation of formal pediatric ASP. Rates of piperacillin-tazobactam susceptibility increased among *E cloacae* and *K pneumoniae*. Other significant increases in susceptibility rates included *P aeruginosa* to gentamicin and *E coli* to cefoxitin. We did not observe any significant decrease in bacterial susceptibility to specific antimicrobial agents between the 2 time periods. *S aureus* susceptibilities, for both methicillin-sensitive and hospital-acquired (>48 hours after admission) methicillin-resistant isolates, remained relatively stable over the 5 years, although

TABLE 2 Median (IQR) Monthly Use of Selected ASP-Targeted Antimicrobial Agents in DOTs/1000 PDs

Antibiotic Name	Before ASP, 2010 and 2011	After ASP, 2014 and 2015	Absolute Change	*P*
Antibiotics audited by pediatric ASP				
Cefepime	52.1 (34.9–57.7)	45.6 (37.1–57.6)	↓6.5	.770
Ceftazidime[a]	4.0 (0.2–6.0)	0.0 (0.0–2.7)	↓4.0	.006
Ciprofloxacin	7.5 (4.5–13.1)	10.3 (5.4–14.7)	↑2.8	.321
Clindamycin	18.9 (16.1–27.8)	17.0 (12.8–27.4)	↓1.9	.284
Levofloxacin	2.2 (0.0–6.9)	1.3 (0.0–3.8)	↓0.9	.221
Meropenem	14.1 (2.9–23.5)	17.9 (11.0–30.1)	↑3.8	.180
Piperacillin-tazobactam[a]	43.8 (35.6–56.2)	21.7 (27.1–44.9)	↓22.1	.034
Rifampin	4.3 (1.7–8.1)	3.2 (0.15–9.5)	↓1.0	.649
Tobramycin[a]	3.1 (1.1–6.2)	0.0 (0.0–2.4)	↓3.1	.001
Vancomycin IV[a]	119.6 (103.1–134.9)	99.7 (89.0–117.7)	↓19.9	.015
Linezolid[a]	0.0 (0.0–1.9)	3.4 (0.8–6.7)	↑3.4	.005
Micafungin[a]	0.0 (0.0–0.0)	8.4 (0.15–18.9)	↑8.4	.0005
Liposomal amphotericin[a]	7.6 (4.3–15.2)	2.7 (0.0–6.5)	↓5.1	.002
Commonly used non-ASP-targeted antibiotics				
Ampicillin	124.3 (102.0–132.9)	105.6 (92.6–120.4)	↓18.7	.076
Ampicillin sulbactam	14.5 (7.2–23.2)	21.2 (12.5–26.5)	↑6.7	.091
Nafcillin and oxacillin combined[a]	8.6 (6.3–14.1)	6.3 (2.7–7.3)	↓2.3	.016
Cefoxitin[a]	0.0 (0.0–1.3)	3.1 (2.3–7.0)	↑3.1	.001
Cefotaxime	48.1 (37.6–58.4)	40 (29.0–48.8)	↓8.1	.266
Ceftriaxone[a]	28.7 (25.3–41.2)	42.8 (38.9–51.3)	↑14.1	.001
Trimethoprim-sulfamethoxazole	15.6 (11.1–20.3)	15.6 (13.5–22.8)	0	.433
Gentamicin[a]	87.4 (71.0–97.7)	65.5 (56.1–81.6)	↓21.9	.001
Fluconazole	15.9 (10.6–32.4)	17.1 (12.5–24.3)	↑1.2	.837

[a] Significant change in antimicrobial use since initiation of pediatric ASP.

methicillin-sensitive *S aureus* (MSSA) susceptibility to clindamycin significantly increased, most likely reflecting a change in circulating strain in the community.

DISCUSSION

The most effective inpatient pediatric ASP strategies to optimize antimicrobial use and enhance patient safety remain unknown. At our institution, pediatrics is a smaller service within a larger medical center. By virtue of its nimbleness and size, we had an opportunity to trial an alternative approach to the established adult medicine ASP program. A key strategy used specifically by the pediatric ASP was the audit and feedback system in which provider autonomy was encouraged, with assistance in appropriate antimicrobial utilization at 48 to 72 hours post-admittance offered when additional clinical information was available. We wish to underscore the importance of provider autonomy and friendly correspondence with ASP interventions because it has been demonstrated that a strong relationship between the members of ASP and the frontline providers account for the high rate of accepted interventions and adherence to clinical practice guidelines.[20] In addition, there was initial hesitation on the part of some pediatric ID faculty to support the pediatric ASP that may have stemmed from a presumption that the ASP would reduce the need for an ID consultation and hence, decrease consultant revenue. We found an increase in ID consultations (normalized for total inpatient days) in the pediatric ASP post-implementation period, indicating that the opposite may be true.

One of the major goals of any ASP is to improve the appropriateness of antimicrobial prescribing. In a little over a year after initiating our formal pediatric ASP, we found that clinical practice and antibiotic guidelines applied to 44% of the antimicrobial orders. We hypothesize that cycles of education and re-education and ready access to guidelines in a central intranet site accounted for the rapid adherence.

The impact of our prospective audit with recommendation and feedback process correlated with reduced antimicrobial utilization after implementation of the program. Indeed, the length of antimicrobial therapy significantly decreased post-implementation of formal pediatric ASP. Unlike in a restricted stewardship program, the decision to limit antimicrobial use is made when additional clinical and laboratory information is available. Approximately 1 in every 6 interventions was for discontinuation of antimicrobial agents. We found this plausible because other studies show antimicrobial agents are often not discontinued in the hospital after they are initiated for suspected infections, even after it is determined that no

TABLE 3 Percent of Bacteria Susceptible to Antibiotic

ASP	Bacteria	*N*	Ampicillin	Cefepime	Cefoxitin	Ceftriaxone	Cefuroxime	Ciprofloxacin	Gentamicin	Piperacillin-tazobactam	Clindamycin	Trimethoprim-sulfamethoxazole
Pre	*A baumannii*	17	—	77	—	—	100	69	82	93	—	88
Post	*A baumannii*	15	—	80	—	—	—	80	87	100	—	87
Pre	*E cloacae*	32	—	94	—	59	0	97	94	43*	—	88
Post	*E cloacae*	18	—	100	—	56	—	100	94	67*	—	89
Pre	*E coli*	70	—	94	87*	91	100	89	91	89	—	70
Post	*E coli*	61	—	98	97*	90	100	82	82	97	—	71
Pre	*K pneumoniae*	36	—	92	92	92	—	94	97	90*	—	89
Post	*K pneumoniae*	31	—	94	94	87	—	97	90	97*	—	81
Pre	*P aeruginosa*	57	—	90	—	0	—	86	79*	91	—	—
Post	*P aeruginosa*	55	—	89	—	0	—	86	89*	86	—	—
Pre	*Serratia marcescens*	11	—	100	—	100	—	91	100	100	—	91
Post	*S marcescens*	18	—	100	—	100	—	100	100	100	—	100
Pre	MSSA	82	—	100	100	—	—	—	96	—	33*	97
Post	MSSA	102	—	100	100	—	—	—	99	—	75*	100
Pre	HA-MRSA	66	—	—	—	0	—	93	89	—	74	97
Post	HA-MRSA	68	—	—	—	0	—	97	88	—	65	74

Unique isolates from pediatric patients were counted once per patient. As per Clinical and Laboratory Standards Institute guidelines, there is less reliability for susceptibility in which there are <30 isolates. Hospital-acquired MRSA defined as cultures performed >48 h after admission. HA-MRSA, hospital-acquired methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*; —, no data.

* Significant differences ($P \leq .05$).

infections exist.[21] Decreasing unnecessary antimicrobial use may avoid adverse effects from antibiotics.

Our antibiotic usage pre- and post-ASP implementation is aligned with our clinical institutional ASP guidelines and prospective audit process. We suspect the decreased DOTs for broad spectrum antipseudomonal antibiotics were secondary to both the audits questioning the continuation of antibiotics when laboratory and radiologic findings were within normal limits and stewardship sepsis guidelines. LOT and DOTs of antibiotics used to "rule out" sepsis cases (ampicillin, gentamicin, vancomycin, cefepime, and cefotaxime) also decreased, likely due to earlier termination of antibiotics in the post- versus pre-ASP. Aminoglycoside guidelines provided clear indications, and decreased usage was aligned to ASP recommendations. We observed vancomycin usage to be inversely related to linezolid in the post-ASP implementation period. We suspect this is secondary to pediatric ASP guidelines recommending an early transition to oral antibiotics for bone, joint, and skin and soft tissue infections. Additionally, audits for modification of therapy often were undertaken to convert intravenous antibiotics to oral.

Other evidence of ASP effectiveness was the decrease in the percentage of bacteria capable of extended-spectrum beta-lactamase production. The percentage of both *E cloacae* and *K pneumoniae* sensitive to piperacillin-tazobactam significantly increased post-ASP, as did *E coli* sensitivity to cefoxitin. The overall trend post-ASP implementation was of stable, or rarely improved, β lactam sensitivity in bacteria capable of producing extended-spectrum beta-lactamase. If the trend continues, this can hold practical relevance as the antibiotic option choices remain stable or even expand for treating what can often be devastating infections in children.

A limitation of this evaluation is generalizability, as we evaluated a single institution's pediatric ASP whose prescribing practices may not be identical to other institutions. We did not directly evaluate clinical outcomes associated with our recommendations, yet many studies show that ASPs improve clinical outcomes.[22–25] Additionally, we do not report on the susceptibility data in the community between the 2 analyzed time periods, which could account for some of the change observed in that data. Finally, we were unable to compare hospitalization costs because of limitations in extracting data from the medical health record during the time period before implementation of the formal pediatric ASP.

CONCLUSIONS

The development and implementation of an ASP program based on the audit and feedback process incorporated with clinical guidelines improved the appropriateness of antibiotic prescribing at a large academic medical institution. We found that a formal pediatric ASP based on prospective audit-and-feedback interventions was widely accepted by providers and led to both improved antimicrobial utilization and restrained the inevitable progression of antibiotic resistance.

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