JPPT | Single Center Retrospective Study

Pharmacy Optimization of Antibiotic Verification and Preparation for Pediatric Emergency Department Patients: A Quality Improvement Project

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OBJECTIVES The primary aim of this project was to improve the rate of prospective pharmacy verification of antibiotics in the emergency department (ED). We also aimed to streamline the process for intravenous (IV) antibiotic preparation and delivery without causing significant delays in antibiotic administration.

METHODS This retrospective evaluation compared pharmacist order verification rates for IV and oral antibiotics pre and post intervention between September 2021 and April 2022. Primary intervention involved modifications to the pharmacist verification queue and workflow prioritization. Process measures included time from order placement to pharmacy verification, pharmacy delivery, and administration. Statistical analysis of median times before and after the process change was conducted by using the Mann-Whitney *U* test. Control charts were used to illustrate the effect of the intervention over the defined period.

RESULTS During the evaluation period, a total of 2545 IV and oral antibiotic doses were ordered in the ED. The process change resulted in an increase in the number of ED IV and oral antibiotic orders verified before administration from 63% (875/1388) to 93% (1076/1157). There were substantial reductions in the pharmacy's median time to IV antibiotic order verification from 21 minutes to 7 minutes (IQR, 4–13; $p < 0.05$), and median time to IV antibiotic order delivery from 43 minutes to 27 minutes (IQR, 18–38; $p < 0.05$). Overall time to the first administrated IV antibiotic remained largely unaffected by the process change (50 vs 51 minutes; $p = 0.16$).

CONCLUSION Implementation of mandatory pharmacy verification and preparation of IV doses in a high acuity environment like the ED is feasible without compromising antibiotic administration times.

ABBREVIATIONS ADS, automated dispensing system; ED, emergency department; IV, intravenous

KEYWORDS antibiotics; emergency; pediatric; pharmacy verification; medication errors

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Introduction

Emergency departments (EDs) are tasked with delivering safe and acute care within a high-pressure environment.[1] In the United States alone, there has been a steady rise in the number of ED visits, reaching an estimated 140 million visits in the year 2021.[2] Specific to the pediatric population, medication error rates in the ED are estimated to be about 3-fold higher than in adult patients with most errors occurring during the prescribing and administration phase; hence, it becomes imperative to use safeguards to reduce the risk of medication errors reaching the patients.[1,3–5]

Pharmacist order review before medication dispensing and administration has been highlighted by numerous studies as a critical safeguard for reducing medication errors, particularly in the pediatric population, due to age-dependent and weight-based dosing.[1] A meta-analysis of 13 studies showed a significant reduction in the medication error rate by about 37% due to pharmacist interventions in the ED.[6] Even in the absence of a physical pharmacist in the ED, remote pharmacist order review can be instrumental in preventing a variety of potential errors, including drug-disease interactions, drug-drug interactions, incorrect drug dose, inappropriate treatment duration, and drug-allergy considerations. In 2007, the Joint Commission issued a strong recommendation, requiring that all medication orders be reviewed by a pharmacist for appropriateness before dispensing, with the exception of medical urgencies or when the medication ordering process is managed by an independent practitioner.[7]

A significant concern with the inclusion of prospective pharmacy verification, particularly in critical settings like the ED, is the potential for delays in medication administration given the importance of timely medication administration and its direct impact on clinical and mortality outcomes.[8–10]

University of Pittsburgh Medical Center Children's Hospital of Pittsburgh is a level 1 trauma center with 46 beds in the ED. The ED evaluates an average of 70,000 pediatric patients per year, without a dedicated ED pharmacist. The inpatient pharmacy department is responsible for the preparation of most patient-specific medication orders, estimated at approximately 110,000 doses per month. In the absence of decentralized pharmacy services in the ED, medications are acquired either via direct delivery from the central pharmacy or through the automated dispensing system (ADS; Acudose-RX, Omnicell Inc, Mountain View, CA). Our ED ADS permits pharmacy override by nursing staff to allow for timely administration of medications, including antibiotics. One notable consequence of this setup is that pharmacy verification often occurs after medication administration. This approach severely limits the pharmacy's ability to proactively prevent medication errors, because pulling the medication from the ADS essentially allows for nursing staff to bypass the prospective pharmacy verification process altogether.

In response to concerns raised by ED leadership regarding the safety of registered nurses performing intravenous (IV) antibiotic calculation and preparation at bed side, coupled with the influx of newly registered nurses during the project period, the primary objective of this study was to improve the rate of prospective pharmacy order review and verification for both IV and oral antibiotics ordered in the ED without compromising medication administration times, as prior studies have demonstrated the feasibility of pharmacy order review in the ED setting, with little to no impact on therapy delays.[11] Our secondary objective was focused on increasing the number of IV antibiotics prepared by the pharmacy department. This approach also helped to ensure additional sterility with medication preparation under a sterile hood, in addition to concentration standardization of IV antibiotics. Also, given the pharmacy's assumption of medication preparation responsibilities, we also sought to improve the pharmacy to ED delivery time for all IV antibiotics prepared.

Materials and Methods

Data Collection and Analysis. This was a retrospective, single center study that analyzed the rate of prospective pharmacy order review of IV and oral antibiotic doses ordered in the ED between September 2021 and April 2022. Data were retrieved from pharmacy order reports, electronic medical records, and pharmacy delivery software. Data collection occurred in 2 separate time frames. The pre-implementation period included antibiotic doses that were ordered in the ED from September 1, 2021, to November 30, 2021. The post-implementation period included antibiotics that were ordered in the ED from January 18, 2022, through April 18, 2022. An extensive educational period occurred from December 1, 2021, through January 17, 2022. Only one-time STAT IV and oral antibiotic doses ordered and administered in the ED were included. Scheduled antibiotic orders, including orders for admitted patients boarding in the ED, were excluded. Data collected included the following: patient identifiers, generic names of antibiotics, dose ordered in milligrams, frequency of administration, order entry time, pharmacy order review time, delivery time, ADS dispensing time, and administration time. Demographic data were collected to link and validate antibiotic orders across 3 separate platforms: pharmacy order reports containing pharmacy verification times, electronic medical records storing administration times, and pharmacy delivery software recording the pharmacy delivery times. Time intervals were calculated between the following for IV antibiotic orders only: order entry time and verification time; order entry time and delivery time, if applicable; and order entry time and administration time for the first IV antibiotic administered.

Descriptive statistics including percentages, median, and IQRs were used to characterize the overall time intervals before and after the process change. The Mann-Whitney *U* test was used to identify the statistical significance of the process change on pharmacy delivery, verification, and administration times. Overall trends in process change were evaluated by using mean control charts. All analyses were performed in Microsoft Excel, Quantum XL (Digital Computations Inc, Orlando, FL), and SigmaZone SPC-XL 2010 (SigmaZone, Orlando, FL). Control charts were shared with ED staff on a weekly to biweekly basis after process change in January 2022.

Intervention. The standard practice prior to the implementation of the project involved the pharmacist receiving a phone call from the ED nurse or receiving an online request form at a printer submitted by the ED nurse. Following this request, ED orders would then undergo pharmacist review, verification, and preparation. Antibiotics that were not formally requested by the nurses were not dispensed by pharmacy because most antibiotic vials were often available for removal directly from the ED's ADS.

The first step was to determine pharmacy's expected workload increase by evaluating historical ED IV antibiotic orders. Our analysis showed a minimal increase in pharmacy's workload on average by about 12 IV antibiotic orders a day based on 3 months of data. This was considered feasible because pharmacy already prepared stock bags of standardized pediatric antibiotic concentrations, which allowed for rapid preparation of

patient-specific doses. Then, to reduce walk and search time for delivered antibiotic orders, we standardized the delivery of IV antibiotics to a centralized location to help streamline the delivery process and improve efficiency for the ED registered nurses.

Pharmacists were then instructed on how to optimize their order queue to allow for easy identification and verification of all ED STAT antibiotic orders. This adjustment prompted an automatic and timely review of all one-time STAT ED antibiotic orders, allowing for the immediate preparation of all pediatric patient–specific IV doses without the need for a phone call or printed request form. The new process ensured sterility and concentration standardization for all IV antibiotics. Following pharmacy preparation, all IV doses were automatically delivered to the designated ED station as soon as possible, irrespective of ADS removal. The goal was delivery of all IV antibiotics to the ED within 30 minutes of the order time. While oral antibiotic doses were also verified by pharmacists, these doses were not delivered, because nursing staff were directed to remove oral doses from the ADS after verification. Throughout the study period, ED nursing staff were encouraged to await pharmacy verification for all IV and oral antibiotic orders prior to dispensing from the ADS.

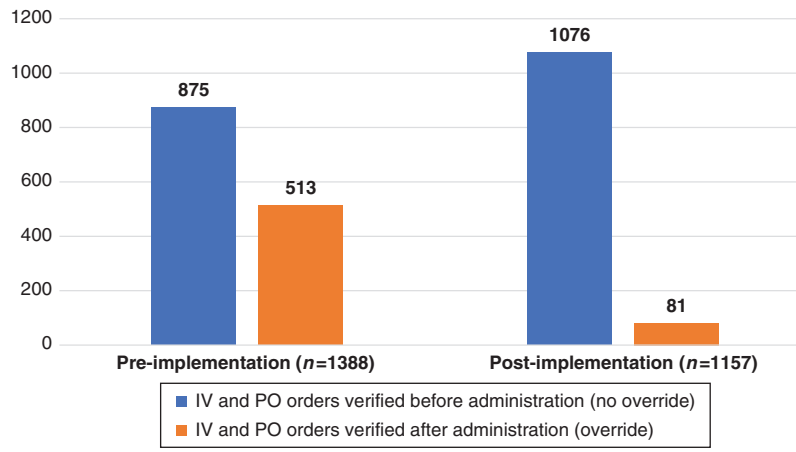
Next, we included about a month-long educational period for all stakeholders, including nursing staff, nursing educators, physicians, and pharmacists on the above process change through various channels. Education was provided through clinical huddles, weekly emails, and at pharmacy and ED staff meetings. Additionally, a formal presentation outlining the project objectives and goals was delivered to pharmacy and ED staff. During the educational period, ED staff were instructed to use pharmacy-prepared IV antibiotics whenever feasible. However, IV antibiotic vials remained available in the ADS for use in urgent situations. Finally, to facilitate a smooth transition period post implementation, timely analysis of the process change in the first weeks of implementation was performed to ensure that there were no significant delays in therapy or harm to the patients due to the new standardized process. Data on verification times, delivery times, and administration times were shared with the ED and pharmacy staff on a weekly to biweekly basis. Furthermore, throughout the post-implementation period we continued to emphasize the importance of entering all antibiotic orders as STAT orders to enable the pharmacy department to quickly identify and prioritize ED orders.

Results

A total of 2545 IV and oral antibiotic orders met the inclusion criteria with 1388 IV and oral antibiotic orders from the pre-implementation group, and 1157 IV and oral antibiotic orders from the post-implementation group. We observed a significant increase in the number of IV and oral antibiotic doses verified before medication administration, increasing from 63% (875/1388) to 93% (1076/1157) in the post-implementation period (Figure 1). Consequently, this improvement resulted in a notable reduction in our override rate for both IV and oral antibiotic orders, decreasing from 37% (513/1388) to 7% (81/1157) (Figure 1).

During the 2 periods, a total of 2030 IV antibiotics were ordered, with 1039 IV doses ordered during the pre-implementation period and 991 IV doses ordered during the post-implementation period. The process change led to an increase in the number of IV antibiotic doses prepared and dispensed by the central pharmacy to the ED from 44% (457/1039) to

Figure 1. Frequency of pharmacist verification for emergency department antibiotic orders pre and post process change implementation (N = 2545).



IV, intravenous; no override, no override by nursing staff prior to pharmacy verification; override, override by nursing staff prior to pharmacy verification.

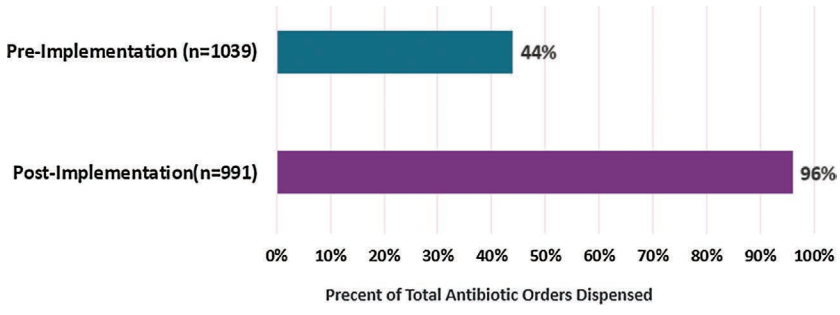
Table 1. Differences in the Median Time From Order Entry to Pharmacy Verification Times and Order Entry to Pharmacy Delivery Times for Intravenous Antibiotics Order Pre and Post Process Implementation*

Time Difference	Pre Implementation (n = 1039)	Post Implementation (n = 991)	p value
Order to pharmacist verification, median (IQR), min	21 (9–45)	7 (4–13)	<0.05
Order to ED delivery, median (IQR), min	43 (28–72)	27 (18–38)	<0.05

ED, emergency department

* Mann-Whitney *U* test analysis of process change for only intravenous doses. Median pharmacist to verification time is calculated as the time difference between the time at order entry and the time at pharmacist verification. Median order to ED delivery time is calculated as the time differences between the time at order entry and the time at order delivery.

Figure 2. IV antibiotics prepared and dispensed by pharmacy to the ED.



ED, emergency department; IV, intravenous.

96% (951/991) (Figure 2). We observed a statistically significant reduction in the median time from order to pharmacy verification pre and post implementation from 21 minutes to 7 minutes ($p < 0.05$), as well as a reduction in the median time to pharmacy delivery from 43 minutes to 27 minutes ($p < 0.05$) (Table 1). An evaluation of the first administered IV antibiotic per patient showed no significant difference in the median time from order to ED administration (50 vs 51 minutes; $p = 0.16$) (Table 2).

Analyzing the data over time with X-Bar (mean) control charts supported the improvements in pharmacy verification and delivery times (Figures 3 and 4). Effects of the process change were seen as early as the start of the educational period and sustained throughout the post-implementation period for both pharmacy verification times and pharmacy delivery times. Although the process change did not reduce the time from order to ED administration for the first administered IV antibiotics, there was no significant change in the median time to first IV antibiotic administered across both study periods (Figure 5).

Discussion

The implementation of the process changes for pediatric patient–specific IV antibiotics by standardizing pharmacy verification and delivery led to a significant reduction in the median time to pharmacy verification from 21 minutes to 7 minutes, with 93% antibiotic orders verified prior to administration (Table 1 and Figure 1). Additionally, this standardization led to a significant reduction in pharmacy delivery times, decreasing the median order entry to ED delivery time by 16 minutes (Table 1).

The impact of pharmacy verification is shown to have a positive effect on patient care, with several studies and institutions repeatedly recounting its influence in the reduction of medication errors as well as a potential cost-saving incentive. Publications such as those of Barra et al[10] and Sin et al[11] have also demonstrated applicability of prospective medication order reviews by pharmacists in an ED setting. Following our intervention, similar to Barra et al,[10] who reported an increase in the percentage of medication orders verified by their pharmacy department from 50% in phase I to 94% in phase II, we observed a significant increase in the percentage of IV and oral antibiotics verified by our pharmacist from 63% pre implementation to 93% post implementation. Likewise, as reported by Barra et al,[10] who observed a reduction in the number of ED overrides from 13.3% to 4.3%, we appreciated a significant reduction in our override rate from 37% to 7% by the end of the study period.

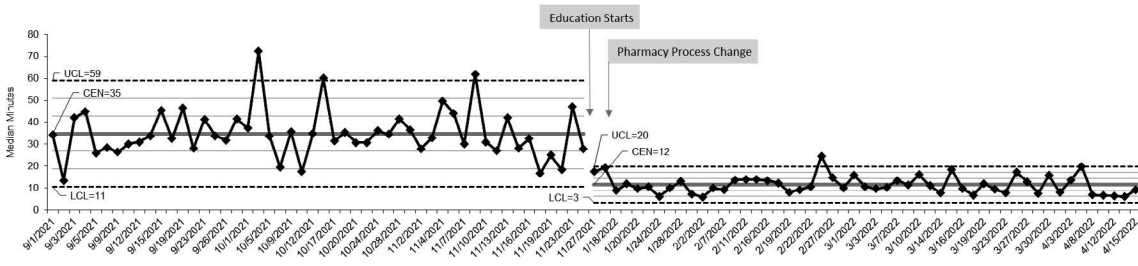
Similar to the studies of Barra et al[10] and Sin et al[11]—who were able to maintain median order entry to pharmacist verification times of 3 to 5 minutes (1–9 minutes) and 4 minutes (2–8 minutes), respectively—following the implementation of prospective pharmacy review in

Table 2. Differences in the Median Time From Order Entry to Emergency Department Administration for Only the First Administered Antibiotic Per Patient Pre and Post Process Implementation*

Time Difference	Pre Implementation (n = 823)	Post Implementation (n = 747)	p value
Order to first antibiotic administration, median (IQR), min	50 (30–83)	51 (32–80)	0.16

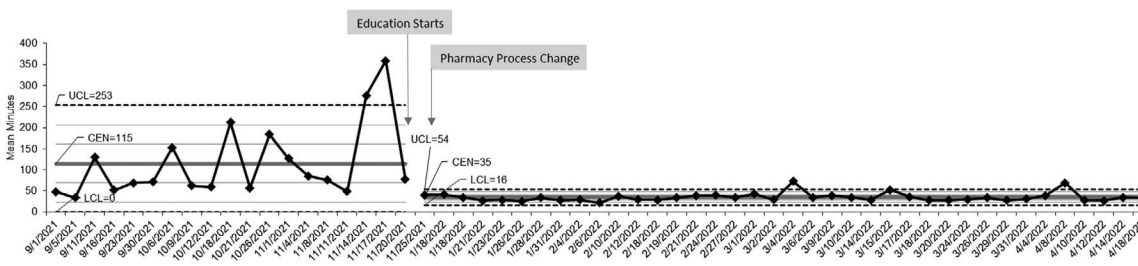
* Mann-Whitney *U* test analysis of process change for only the first administered intravenous doses. Median order to first antibiotic administration is calculated as the time difference between the time at order entry and the time at order administration.

Figure 3. X-bar control chart: mean time to order verification for IV doses only. Each data point represents 20 chronologic IV antibiotic orders.



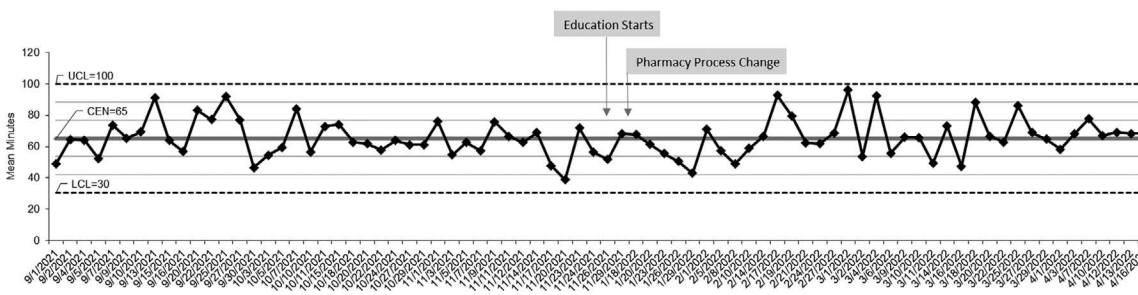
CEN, center line (mean); IV, intravenous; LCL, lower control limit; UCL, upper control limit.

Figure 4. X-bar control chart: order to ED delivery time for IV doses only. Each data point represents 20 chronologic IV antibiotic orders.



CEN, center line (mean); ED, emergency department; IV, intravenous; LCL, lower control limit; UCL, upper control limit.

Figure 5. X-bar control chart: order to administration of first antibiotic per patient for IV doses only. Each data point represents 20 chronologic IV antibiotic orders for the first IV antibiotic administered to the patient in the ED.



CEN, center line (mean); ED, emergency department; IV, intravenous; LCL, lower control limit; UCL, upper control limit.

our ED, we were able to achieve a median order entry to pharmacist verification time of 7 minutes (4–13 minutes), which was a significant decrease from our pre-implementation times of 21 minutes (9–45 minutes). While our observed median time to order verification was longer than that of our predecessors, this disparity may be attributed to the lack of a physical pharmacist in our ED. Additionally, while we did not investigate the impact of pharmacist shift times, we recognized that our limited staffing resources during our evening and overnight shift may have affected our overall time from order entry to pharmacist verification.

While the aforementioned studies[10,11] also showed additional benefits including a reduction in time to first antibiotic administration and reduction in delays to patient care, our study was able to show that even when the pharmacy department was responsible for antibiotic preparation and delivery, there was little to no impact on antibiotic administration times in the ED. Like its predecessors, this study supports the feasibility of pharmacy order review in a high acuity setting like the ED. The influx of newer nursing staff, coupled with ED leadership concerns for potential errors with antibiotic preparation at bedside, prompted us to evaluate the applicability of IV antibiotic preparation and delivery by the inpatient pharmacy department to promote concentration standardization in combination with timely administration.

Implementation of a process change does not guarantee success, and the methods of implementation can be as important as, if not more important than, the intended change itself. The successful execution of our standardized process change depended heavily on input from all participants in the process: physicians, pharmacists, technicians, and nurses. Our pre-implementation, multidisciplinary discussions assessed needs, fit, and resistance to change. We attribute most of the success of this project to the early involvement of the process participants as well as getting support from the managers and leaders of each department, all who encouraged a cultural shift to the implemented change.[12–14] In addition, the comprehensive education provided via multiple methods was crucial to the success of this project.

This project has its limitations, which includes the lack of data collection on pharmacist interventions. While this would have greatly helped solidify the safety aspect, these were not collected owing to inconsistencies in pharmacist documentation of interventions in the electronic health record. We were unable to calculate the actual preparation time for the stock bags and the IV antibiotics, owing to the lack of documentation on preparation times in our sterile IV preparation room, which could have been instrumental in further expediting pharmacy preparation times. Like seen nationwide, staffing shortages did significantly affect both nursing and pharmacy departments, which could have affected our preparation and administration times. Human error led to some missing delivery barcode scanning times, so we did not have comprehensive delivery time data. It is important to note that while our focus was primarily on improving antibiotic order verification, preparation, and delivery to the ED, the potential effects of this process change on other units within the hospital was not analyzed. Finally, we did not collect data on medication administration near-misses or errors.

Conclusion

Implementation of prospective pharmacy order review without sacrificing time to antibiotic administration is feasible in a demanding environment like an ED even without a dedicated ED pharmacist. Further analysis is necessary to determine the clinical and safety impact of prospective pharmacy order review in the ED.

Article Information

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Ethical Approval and Informed Consent. The authors assert that all procedures contributing to this work comply with ethical standards of the relevant international guidelines on human experimentation and have been approved by the appropriate committees at University of Pittsburgh Medical Center (UPMC). However, given the nature of this study, institutional review board/ethics committee review and informed consent were not required. UPMC Quality Review Committee approval was obtained.

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