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ORIGINAL CONTRIBUTION

Prescription Errors Before and After Introduction of Electronic Medication Alert System in a Pediatric Emergency Department

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Abstract

Objectives: Prescription errors occur frequently in pediatric emergency departments (PEDs).The effect of computerized physician order entry (CPOE) with electronic medication alert system (EMAS) on these is unknown. The objective was to compare prescription errors rates before and after introduction of CPOE with EMAS in a PED. The hypothesis was that CPOE with EMAS would significantly reduce the rate and severity of prescription errors in the PED.

Methods: A prospective comparison of a sample of outpatient, medication prescriptions 5 months before and after CPOE with EMAS implementation (7,268 before and 7,292 after) was performed. Error types and rates, alert types and significance, and physician response were noted. Medication errors were deemed significant if there was a potential to cause life-threatening injury, failure of therapy, or an adverse drug effect.

Results: There was a significant reduction in the errors per 100 prescriptions (10.4 before vs. 7.3 after; absolute risk reduction = 3.1, 95% confidence interval [CI] = 2.2 to 4.0). Drug dosing error rates decreased from 8 to 5.4 per 100 (absolute risk reduction = 2.6, 95% CI = 1.8 to 3.4). Alerts were generated for 29.6% of prescriptions, with 45% involving drug dose range checking. The sensitivity of CPOE with EMAS in identifying errors in prescriptions was 45.1% (95% CI = 40.8% to 49.6%), and the specificity was 57% (95% CI = 55.6% to 58.5%). Prescribers modified 20% of the dosing alerts, resulting in the error not reaching the patient. Conversely, 11% of true dosing alerts for medication errors were overridden by the prescribers: 88 (11.3%) resulted in medication errors, and 684 (88.6%) were false-positive alerts.

Conclusions: A CPOE with EMAS was associated with a decrease in overall prescription errors in our PED. Further system refinements are required to reduce the high false-positive alert rates.

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Medication errors occur more frequently in children than in adults.[1] Some of the postulated reasons for these increased rates of medication errors in children are the need to calculate doses based on weight and the need to reformulate many medications, which are packaged primarily for adults.[2] Pediatric emergency departments (PEDs) are a particularly vulnerable area for medications errors,[3] with a 10% to 12% prescribing error rate.[4,5]

In an effort to reduce medication errors in children, many institutions have implemented computerized physician order entry (CPOE).[6,7] Implementation of CPOE

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can decrease medication errors significantly. In a meta-analysis of 25 studies that evaluated the effects of CPOE on the medication error rate, 23 showed statistically significant relative risk reductions of 13% to 99%.[8] However, Bobb et al.[9] found that 13.2% of these errors could not be prevented by CPOE alone. More importantly, prescribing errors with the potential for patient harm were less likely to be prevented.[9]

Therefore, refinement of CPOE with clinical decision support systems is being promoted as a tool to reduce prescription errors. Clinical decision support can provide either basic (e.g., drug allergy checking) or advanced (e.g., drug dosing support for renal insufficiency) guidance for the prescriber. In a systematic review of 10 studies evaluating CPOE with clinical decision support systems, five were associated with statistically significant decreases in adverse drug events.[10] However, these studies were performed in either inpatient hospital settings or outpatient clinics. The effect of such refined CPOE systems in the PED, particularly on the outpatient prescription medication errors, is not known. Our institution introduced decision support (electronic medication alert system [EMAS]) to our existing CPOE for outpatient prescriptions in 2010. The software alerts the clinician to errors in dosing, frequency, drug allergy, and drug-to-drug interactions and provides the prescriber with the opportunity to modify the prescription. The objective of this study was to test the hypotheses that addition of the EMAS to existing CPOE reduces the rate and severity of outpatient prescription errors in the PED.

METHODS

Study Design

This was a prospective before-and-after study of outpatient medication prescriptions provided to children younger than 18 years, who were discharged from our PED. This study was approved by our institutional review board.

Study Setting and Population

The study was performed at an inner-city PED with approximately 92,000 visits per year, in a free-standing children's hospital that is a Level I trauma center. Of the total visits to our PED, 88% of patients are discharged home; nearly 50% of these are provided medication prescriptions.

The preimplementation period included the 5-month period of January 2010 through May 2010. The decision support was implemented in October 2010. The postimplementation period included the 5-month period of January 2011 through May 2011. A randomly selected sample of prescriptions from the preimplementation period was compared with a similarly selected sample postimplementation. Prescriptions were excluded if they were for equipment or medical supplies, such as nebulizers. Medication orders that were written on admitted patients or as part of ongoing patient care prior to discharge from the PED were not reviewed.

Electronic Medication Alert System. Our PED implemented CPOE in December 2006, using Cerner (Cerner Corporation Inc., Kansas City, MO; version 2007.19.12), which was then upgraded in August 2010 with the addition of EMAS. This was introduced to alert the prescriber to the presence of drug allergies, dose range checking, harmful drug-to-drug interactions, and drug frequency errors in outpatient prescriptions.

Study Protocol

For the duration of the study, an automated report of all children who were discharged home from the PED with medication prescriptions was provided by the information technology support personnel. There were 19,358 patient visits during the pre-EMAS period and 17,362 patients visits during the post-EMAS period. A simple random sample of 5,000 patient visits (including multiple prescriptions per patient) pre-EMAS (from a total of 19,358 patients) and post-EMAS (from a total of 17,632 patients) was generated using Minitab 17 for analysis during each study period. The total number of patient visits during the period and the sample size required was entered into Minitab, which then generated a list of 5,000 random numbers. No limitations were entered into the system; hence, each patient had the same chance of being selected. Patient visits were entered into an Excel sheet in order of the date and time of presentation. The number generated by Minitab was then matched to the corresponding patient in the Excel spreadsheet. This study sample of patient visits was cross-checked against the whole, and the similarity in proportions of distributions between the two in type of prescription, month and time of prescription, and provider type was confirmed.

Two study research assistants abstracted the following information from the medical record into an Excel spreadsheet: patient's age, demographics, weight, known drug allergies, diagnosis for which the drug was prescribed, time and date of prescription, prescriber type (attending, resident, fellow, or nurse practitioner), medication type, and details of the prescription such as dose, frequency, and duration of therapy. During the post-EMAS period, additional information included alert generation, the type of alert to the drug prescribed (drug–drug interaction, dose range checking, frequency, drug–food allergy, drug duplicate orders, and drug allergy) and physician response to the alert (override or modify). The EMAS tracked physician responses to only the dose range checking alerts, and hence only these were available for analysis.

The spreadsheet was then made available to a single study pharmacist (KPM), who was working full time on this study. The study pharmacist also had access to the entire electronic medical record, including information regarding weight of the child, presence of medication allergies, diagnosis, and the electronic prescription provided to the patient. This pharmacist, who was not blinded to the date of the prescription, then analyzed all prescriptions over a period of 2 months each (pre- and post-EMAS) for the presence of dosing errors (defined as >10% deviation of the weight- or age-appropriate dose as recommended in pediatric Lexi-Comp), drug allergy errors, drug–drug interactions, and dose frequency errors.

Errors were then classified as serious if they met one of the following criteria: 1) potential to cause life-threatening injury, 2) potential to cause failure of therapy, or 3) potential to cause non–life-threatening adverse drug effects (e.g., diarrhea with antibiotics).

Based on those definitions, the study pharmacist also classified alerts as serious or nonserious. The study principal investigator (US) then randomly reviewed 20% of the prescriptions (2,912 prescriptions) to verify accuracy of the pharmacist's classification of errors. In cases of discrepancy of error and alert classification between the pharmacist and the principal investigator (PI), the decision of the PI was considered as final.

Data Analysis

All data were entered into an Excel spreadsheet (version 2002) by a single research assistant and variables were systematically coded for analysis. Inter-rater reliability was measured using kappa statistic. Descriptive statistics were used to describe the study sample, medication error rates, and error types. Poisson rate ratio was used to compare the differences in the medication error rates between prescriptions in the pre- and post-EMAS groups, with no serious overdispersion detected in the data. Error rates are expressed as errors per 100 prescriptions. All statistical tests were two-tailed and performed at the 5% level of significance. The confidence intervals (CI) for the percentages were calculated as 95% CI. For patients with more than one prescription, we also measured the proportion of errors that occurred with the last prescription. We used an interrupted time-series analysis, with segmented linear regression, to estimate the change in error rate and the change in the slope of error rates after the intervention. We used the autoregressive time series analysis with Cochrane-Orcutt method to correct for the autocorrelation effect in the time series.

All data were analyzed using SPSS version 21. We had performed a preliminary review of error rate in outpatient prescriptions in our ED as part of a quality improvement initiative. This provided us the baseline error rate of 15%. A previous study from a pediatric intensive care unit showed a reduction in potential medication adverse events from 2.4% to 0.7% between two periods which used CPOE and CPOE with clinical decision support system, respectively. Sample size calculation using a baseline error rate of 15% and a reduction of 2% to achieve a power of 80% required a sample size of 4,724 patient visits per study period.

RESULTS

We analyzed 10,000 patient visits, with 14,560 prescriptions (7,268 pre- and 7,292 post-EMAS). The kappa for agreement between the pharmacist and the PI regarding classification of error and alerts was 0.75 (95% CI = 0.49 to 1).

Patient demographics and prescription characteristics are shown in Table 1. Overall, during the study period, there were 8.88 errors per 100 prescriptions. The most common medication errors involved antibiotics. The most common type of error was a dosing error, which was significantly reduced in the post-EMAS period (Table 2).

Table 1
Patient Demographics and Prescription Characteristics Before and After EMAS Implementation

Variable	Pre-EMAS	Post-EMAS	p-value
Sex			
Male	2,638 (52.8)	2,682 (53.6)	0.378
Female	2,362 (47.2)	2,318 (46.4)	
Age group (yr)			
<1	647 (12.9)	727 (14.5)	0.214
1–5	2,301 (46)	2,264 (45.3)	
6–10	1,068 (21.4)	1,034 (20.7)	
11–15	728 (14.6)	731 (14.6)	
>16	256 (5.1)	244 (4.9)	
Number of medications prescribed			
1	3,238 (64.8)	3,206 (64.1)	0.566
2	1,284 (25.7)	1,287 (25.7)	
≥3	476 (9.5)	507 (10.1)	
Time of day (hr)			
7:01–15:00	1,509 (30.2)	1,496 (29.9)	0.663
15:01–23:00	2,277 (45.5)	2,251 (45.0)	
23:01–7:00	1,214 (24.3)	1,253 (25.1)	
Prescriber type			
PEM attending	1,539 (30.8)	1,525 (30.5)	0.000
Pediatrics attending	673 (13.5)	551 (11)	
PEM fellow	303 (6.1)	303 (6.1)	
Resident	2,087 (41.7)	2,140 (42.8)	
Nurse practitioner	398 (8)	514 (10.3)	

Data are reported as *n* (%).
EMAS = electronic medication alert system; PEM = pediatric emergency medicine.

Table 2
Type of Errors Before and After EMAS Implementation

Type of Error	Pre-EMAS	Post-EMAS	p-value
Dosing	582 (8)	398 (5.4)	<0.0001
Frequency	110 (1.5)	96 (1.3)	0.3243
Drug-to-drug interaction	8 (0.1)	7 (0.1)	0.7961
Allergy	17 (0.2)	6 (0.1)	0.0217

Data are reported as *n* (%).
EMAS = electronic medication alert system.

There was a statistically significant reduction in the overall error rate between the pre- and post-EMAS periods (10.4 per 100 prescriptions preimplementation vs. 7.3 postimplementation, absolute risk reduction = 3.1%, 95% CI = 2.2% to 4%). This was primarily due to a decrease in drug dose errors, which decreased from 8 per 100 to 5.4 (absolute risk reduction = 2.6 per 100, 95% CI = 1.7 to 3.3). There was no decrease in the rate of prescriptions with serious errors (pre-EMAS, 4.9 per 100; post-EMAS, 4.5 per 100; absolute risk reduction = 0.4 per 100, 95% CI = –0.3 to 1.0). A time-series analysis of the above effect of EMAS on medication error reduction is shown in Figure 1. There was a statistically significant change in both the overall error rate ($p < 0.01$) and the slope of the rate of change of error rate ($p = 0.006$) comparing the pre- and post-EMAS periods. Among patients with multiple prescriptions, the majority of the medication errors occurred in the last prescription, and this was significantly reduced in the

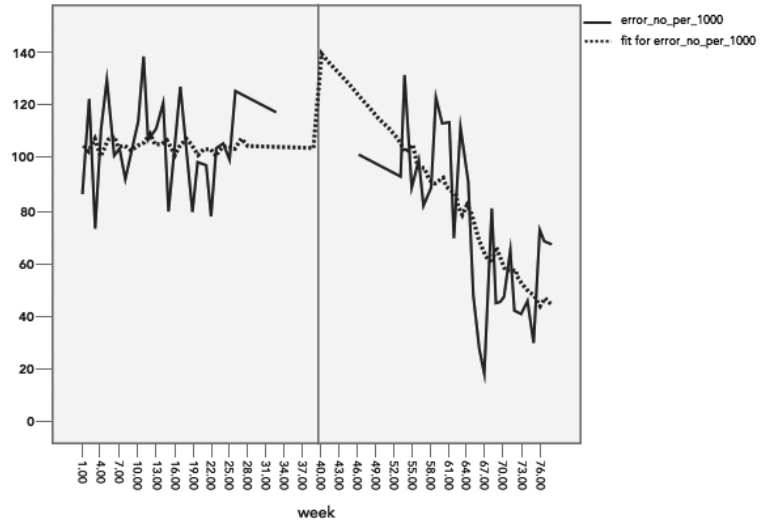

Figure 1. Time-series analysis showing prescription errors before and after electronic medication alert system implementation.

post-EMAS period (pre-EMAS 611 of 735 [80.9%] vs. post-EMAS 395 of 531 [74.2%]; $p < 0.05$).

Alerts were generated for 2,161 (29.6%) prescriptions in the post-EMAS period, of which 6% were serious. Overall, the sensitivity of EMAS alerts in identifying errors in prescriptions was 45.1% (95% CI = 40.8% to 49.6%) and the specificity was 57% (95% CI = 55.6% to 58.5%). Of the total alerts, 959 (44.4%) involved drug dose range checking, 317 (14.3%) drug–drug interactions, 510 (23.6%) drug duplicate, eight (3.7%) drug allergy, 236 (10.9%) drug-to-food allergy, and 128 (5.9%) involved multiple alerts.

Among the 959 prescriptions that had dose range checking alerts generated, 187 (19.5%) were modified by the physician, thus preventing the error from reaching the patient. Alerts were ignored or overridden by the physician for 772 prescriptions, of which 88 (11.3%) resulted in medication errors, and 684 (88.6%) were false-positive alerts.

DISCUSSION

Computerized physician order entry with clinical decision support was associated with a reduction in reducing outpatient medication prescription errors by 29% in our PED, but not with the reduction of serious errors. The observed reduction in errors was predominantly related to a decrease in antibiotics errors and dosing errors. This reduction came at a cost to users of approximately 43% false-positive alerts and overriding of important dose range checking alerts in 11% of prescriptions. This suggests that the decision support needs refinement to improve its specificity.

To our knowledge, this is the first study of its kind conducted in a pediatric ED. The ED has the highest rate of medication errors (6%) and preventable adverse drug events in hospitals.[3,11,12] Despite the high rates of errors among prescribed medications, there are scant data in literature regarding the efficacy of CPOE with or without clinical decision support systems in pediatrics and particularly in the PED. Further, those studies that do exist in the pediatric literature have been conflicting in whether CPOE with clinical decision support systems reduces medication errors. Kadmon et al.[13] investigated the change in prescription error rates with the introduction of CPOE with and without a clinical decision support system limited to weight-based dosing in a pediatric intensive care unit. They showed that while the introduction of CPOE reduced the potential adverse events and medication errors only slightly, the addition of a clinical decision support system reduced these errors significantly.[13] Walsh et al.[14] also reported a minor reduction in prescription errors in a pediatric hospital using a CPOE with dosing checking alerts. In contrast, Mullett et al.[15] found no difference in their study of adverse drug events due to anti-infective therapy with implementation of CPOE with clinical decision support system in an pediatric intensive care unit.

In the only other study from the pediatric ED, Sard et al.[16] reported a 55% reduction in medication prescribing errors after implementation of a local clinical decision support system called "quick list." We observed a similar, albeit smaller, drop (29%) in the error rates after implementation of EMAS. Possible explanations for the observed difference in decreased error rates between the two studies are that our study only included medication prescriptions at discharge and studied only four specific medication errors. We did not include duplicate orders, details such as missing weight, and hospital policy violations that were included by Sard et al.[16]

One finding in our study was that errors were more likely to occur when there were multiple prescriptions for a single patient and were more likely to occur with the last prescription. While our study design did not allow us to determine the reasons for this, it is possible that prescriber fatigue occurs with successive prescription writing. Alternatively, providers may feel rushed to complete multiple prescriptions to maintain patient throughput. Whatever the reason, this error in the last prescription was significantly reduced in the post-EMAS period, suggesting that clinical decision support systems can directly affect this area of error.

We observed no difference in serious error rates pre- and post-EMAS. This is likely related to the rarity of serious errors. A study demonstrating a reduction of serious errors from 4.9% to 4.5%, the rates in our study, would require approximately 44,000 patients in each group to achieve 80% power.

It is important to note that only 19.5% of alerts were accepted by physicians, resulting in modifications of flawed prescriptions. Perhaps equally important is the fact that 11% of alerts for true errors were overridden by the prescriber. Reports of overriding the alert by the prescriber range from 49% to 96% in literature.[17] Reasons cited for alert override include alert fatigue, physicians' faith in their own knowledge, and difficulty in interpretation of the alerts and the clinical consequences. In this study, the high rate of false-positive alerts generated could have contributed to alert fatigue, leading to clinicians overriding important alerts. One of the reasons for the high rate of false-positive alerts is that our clinical decision support system was not designed to consider the specific indication for which the drug was ordered (e.g., normal versus high-dose amoxicillin for otitis media) or the patient's underlying clinical status (e.g., renal function). In addition, one-fifth of the alerts that were generated were for duplicate prescriptions. Our study results thus suggest that while CPOE with clinical decision support was associated with decreased error rates among outpatient prescriptions in the PED, further refinements are needed to decrease the false-positive alert rates.

LIMITATIONS

We evaluated only a random sample of outpatient prescriptions during the study period. It is possible that the overall error rate and the reduction would have been different if we had studied all prescriptions written during the study period. However, the prescriptions that were analyzed were randomly selected, thus decreasing the likelihood of bias. We also did not account for potential unmeasured confounding variables or secular trends that might have contributed to the reduction in errors in the post-EMAS period. However, EMAS was the only change to the prescribing process that was implemented during the study period.

A further limitation of the study is that we did not evaluate the number of the prescription errors that actually resulted in patient harm. We were able to evaluate physician responses only to dose range checking alerts and not for the other type of alerts. Further, we did not study the reasons behind the physician responses to the alerts; as with our existing EMAS, physicians have an option of not providing this. None of the study personnel who reviewed the prescriptions for errors were blinded to the prescription date and hence may have been inherently biased, which may have influenced the error rate.

CONCLUSIONS

The addition of clinical decision support to an existing computerized physician order entry was associated with a reduction in the overall electronic, ambulatory prescription errors in our pediatric emergency department. There was, however, no reduction in the rate of serious medication errors. This alert system was associated with high false-positive rates. Further refinements are required to improve specificity and reduce prescriber alert fatigue.

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