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ORIGINAL RESEARCH

Electronic Prescribing at a Publicly-Funded, Safety-Net Hospital Reduces Rates of Medication Safety Errors and Formulary Compliance Issues

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Background

Medication errors are common; up to 630,000,000 prescriptions with errors are written annually in the U.S.[1] Prescribing errors (any deviation from a complete, accurate, and legible prescription[2]) are commonly related to dose, frequency,[3,4] and legibility.[5] They are often errors of "omission" with missing or incomplete information to appropriately or legally dispense a medication.[6] Pharmacists intervene on 1-5% of prescriptions.[7,8,9] Electronic prescribing (e-prescribing) reduces prescribing errors[10] and is safer[11] and more formulary-compliant,[12] improving legibility and appropriateness.[11,13] Federal initiatives such as the Centers for Medicare and Medicaid Services' (CMS's) eRx Incentive Program and the Office of the National Coordinator for Health Information Technology's Meaningful Use adoption of an e-prescribing core measure[14] provide additional motivation for organizations to adopt e-prescribing. In 2012, our hospital implemented an electronic medication reconciliation module with electronic prescribing and prescription printing linked to our health system's formulary.

Rationale

This study evaluates the impact of e-prescribing on medication errors as assessed by pharmacy interventions for safety errors or formulary compliance issues, comparing error rates using handwritten prescriptions vs. electronically-generated prescriptions in a medically-underserved population. Underserved populations differ from

populations with better healthcare access in ways that might attenuate the safety benefits of e-prescribing. Prescribers are less likely to make errors when prescribing medications with which they are familiar.[15] Underserved populations have less access to newly-approved medications.[16] With fewer newly-approved medications available to prescribe, prescribers may commit fewer prescribing errors. Consequently, safety benefits of e-prescribing in reducing prescribing error rates may be less apparent among underserved populations.

Methods

Our hospital is a 377-licensed bed, publicly-supported, academic teaching hospital of the Los Angeles County Department of Health Services (DHS) providing inpatient and operative services, and outpatient adult and pediatric generalist and specialty care at clinics located in the hospital building. It is staffed to 200 beds and serves an indigent, largely immigrant population. At the time of the intervention, the hospital did not have an electronic health record (EHR) or other electronic prescribing software.

In 2012 to address medication management, we modified slightly the existing, in-house-programmed emergency department information system– Advanced Triage and Emergency Medicine Management (ATEMM)–into a clinic tracking system. End-users participated in user interaction and user interface design. By the end of 2012, ATEMM was used in every clinic other than Ophthalmology/Otolaryngology Clinic. ATEMM includes prescription printing (without clinical decision support) linked to our health system's formulary. Appropriate fields were required to be completed before the prescription would print. Fields with prescribing abbreviations (e.g., "BID" for "twice daily") were limited to approved abbreviations. However, so as not to limit prescribing freedom, each field allowed a prescriber to "free text" information; for example, though it is uncommon to prescribe a medication to be taken 6 times/day, if a provider so desired, the means to do so would be to free text "6 times/day." Items entered in free text were not checked by ATEMM for banned abbreviations. Prescriptions were handwritten prior to 2012.

We assessed the impact of e-prescribing via ATEMM on prescription error rates at our hospital's clinics where ATEMM was utilized by the start of 2013 (all clinics other than the Ophthalmology/Otolaryngology clinic). We compared error rates for medications from the last full year prior to ATEMM implementation (2011) vs. the first two full years of ATEMM usage (2013 and 2014). Data on prescribing errors or formulary compliance issues for prescriptions written from clinics was obtained from the pharmacy electronic error intervention reporting system (Quantifi® Pharmacy OneSource, Inc.,

Bellevue, WA). Description in Quantifi® of the error and intervention is mandatory when a communication to prescriber or intervention is made. Entries are only made by pharmacists, not pharmacy technicians. Entry fields include error date, location/service (e.g., Primary Care Clinic) the prescription originated from, medication, error type (e.g., dose, legibility), intervention, time spent addressing error, and outcome notes. Errors were categorized by the authors as being for "safety," for "formulary compliance issue," or "other." Authors categorized interventions as for "safety" if they regarded strength, dose, route, frequency, quantity, duplicate therapy, legibility, or unapproved abbreviation, or if the description of error incidents labelled "Other intervention" suggested a safety error that e-prescribing through ATEMM could have prevented (e.g., no quantity or date written on prescription). "Formulary compliance issues" were those in which the medication prescribed was non-formulary. To ensure we analyzed only relevant errors, we first removed from analysis any errors committed on prescriptions from clinics where ATEMM was not implemented. We then removed from analysis any errors committed on prescriptions for Drug Enforcement Agency (DEA)-scheduled medications, as ATEMM prohibited printing such medications; errors for such medications could not have been made using ATEMM. To assess impact on pharmacist time, we queried Quantifi® for pharmacist time addressing each error. Statistical analyses were performed using Microsoft Excel (2010, Redmond, WA). Statistical significance was set a priori at $p < 0.05$.

The study was approved by our hospital's institutional Investigational Review Board.

Results

In 2011, prescriptions for 142,249 medications were written from our hospital's participating clinics. Of 5,261 errors (3.7%), 2,443 (1.7%) were safety errors and 685 were formulary non-compliance (0.5%), which e-prescribing might have prevented. The remaining errors were not classifiable or were errors that e-prescribing would not prevent (e.g., medications written for wrong patient). In 2013, prescriptions for 149,343 medications were printed from ATEMM in our hospital's clinics. Of 2,331 errors (1.6%), 1,405 were safety errors (0.9%) and 329 were formulary non-compliance (0.2%). In 2014, prescriptions for 146,486 medications were printed from ATEMM in our hospital's clinics. Of 3,839 errors (2.6%), 1,068 were for safety (0.7%), and 123 were for formulary non-compliance (0.1%). Averaging prescriptions from 2013 and 2014, 2.1% of all prescriptions had errors (0.8% for safety and 0.2% for formulary non-compliance). This represents a 43.6% decrease in total errors, 51.3% decrease in safety errors, and 67.0% decrease in formulary non-compliance (53.2% decrease in combined safety errors and formulary non-compliance). All differences between baseline year (2011) and post-implementation years (2013 + 2014 averaged) were highly statistically significant (Table 1, Figures 1-3).

The typology of safety errors included dose errors, drug clarification, duplicate therapy, inappropriate frequency of administration, illegible prescription, inappropriate route of administration, incomplete prescription, prohibited abbreviation, and other intervention (e.g., no quantity or date). The remaining errors described in Quantifi® were for non-formulary medications, "miscellaneous," "not specified," or were clarifications (e.g., ensuring a prescriber wanted to renew a prescription for a medication before the previous prescription was expected to be finished). Table 2 displays the number of each error type and a comparison between pre- and post-intervention years.

Decreases in safety errors and formulary compliance issues translated into a 50% decrease in pharmacists' time (and cost) resolving errors (Table 3, Figures 4-5).

Discussion

E-prescribing resulted in a significant decrease in the number and percent of safety errors and formulary compliance issues compared with handwritten prescription forms. To our knowledge, this is the first study demonstrating the impact of e-prescribing on safety errors and formulary compliance issues at a publicly-operated, safety-net hospital. Error rates decreased by more than 50% after e-prescribing was introduced. Annually, there were over 1,650 fewer such errors reported when comparing the pre-implementation year (2011) to the average of the first two post-implementation years (2013 and 2014). The decrease in safety errors and formulary compliance issues is unlikely attributable solely to trends in hospital-wide error reporting, as the 53.2% decrease in safety errors and formulary compliance issues greatly exceeds the 2.9% decrease in overall hospital-wide errors reported in Quantifi® during this timeframe.

These changes occurred despite reasons to question whether such e-prescribing benefits might extend to safety-net settings. Prescribers make more errors prescribing unfamiliar medications.[15] Underserved populations have less access to newly-approved (i.e., unfamiliar) medications.[16] Safety-net prescribers may, therefore, commit fewer prescribing errors. We found that, despite this, safety errors decreased significantly with the introduction of e-prescribing.

With fewer safety errors and formulary compliance issues, pharmacists spent significantly less time addressing errors via communication or interventions with prescribers. Such time savings allow pharmacists to focus on other services contributing to patient safety (e.g., patient counseling and reviewing prescriptions) and avoid provider disruptions.

Challenges and Future Directions

Because our e-prescribing program was programmed by our health system's information technology staff, we were very responsive to user requests. Obstetricians identified a common source of errors not considered in our original modification from an emergency department information system to a clinic tracking system. Prescribing teratogenic medications (e.g., angiotensin converting enzyme inhibitors, warfarin) to reproductive-age women not on reliable birth control. In response, we recently implemented a process to minimize such prescribing. Before printing a teratogenic medication prescription, ATEMM checks gender and age; if indicative of a

reproductive-age woman, a pop-up box warns the prescriber and allows opt-out of printing the prescription. In the first month, the alert was triggered for 209 prescriptions at 163 out of 3,430 visits (4.8%) by reproductive-age women; in 14 (8.6%) of those 163 visits, the provider opted not to prescribe the alert-generating medication, resulting in 51 cancelled prescriptions out of 209 originally-intended prescriptions (24.4% reduction in teratogenic medication prescribing to this population). Were this 24.4% reduction applied to the 1,485 teratogenic medication prescriptions written for reproductive-age women the prior year, this population would have been exposed to 128 fewer such medications.

We also recognized relying on our health system's pharmacy formulary was insufficient as some commonly-prescribed items are not on the formulary; notably, blood glucose testing equipment (e.g., lancets and test strips). We added those items to the ATEMM's medication table, so they can be quickly looked up and printed on a prescription.

Finally, we took steps to avoid printing duplicate medications. ATEMM imports to each patient's medication reconciliation page any medications dispensed from any DHS pharmacy. Our health system's formulary table does not contain National Drug Codes (NDC codes); rather, ATEMM relies on an exact match of spelling and capitalization to identify medications. If a medication is imported into the medication reconciliation page that has the same name but is slightly different (e.g., Albuterol vs. Albuterol HFA), the system cannot tell there is a duplicate medication. We addressed this by adding a "Duplicate" column to the medication reconciliation page. Providers indicate a medication is a duplicate as such by clicking a "Duplicate" checkbox, which removes the duplicate medication from the medication reconciliation list.

Limitations

This study has several limitations. As a single-site intervention at a publicly-funded hospital serving an indigent, largely immigrant population, results may not be generalizable. The study was performed at an institution that trains house staff and medical students; such benefits may not confer to organizations with more experienced prescribers, who are less-prone to making prescribing errors related to safety errors or formulary compliance. In addition, accuracy of error reporting was pharmacist-dependent; as such, the number and type of reported errors may undercount the true number and type of errors. The intervention rates reported in this study are on the lower end of previously-published error rates (1-5% of prescriptions),[7,8,9] likely due to underreporting. Although reporting errors in Quantifi® was mandatory by policy, it was voluntary in the sense that there was no way to force pharmacists to enter errors. Time pressure and implementation of a new, automated dispensing system may have distracted pharmacists from entering all errors; new staff may not have been as familiar with the system. However, such inter-pharmacist variation and underreporting would likely have been the same pre- and post-implementation of e-prescribing via ATEMM, lending validity that the observed differences in error rates reflect true differences. Finally, although most patients obtain their medications from our hospital, we would have missed errors on prescriptions given to patients who obtain medications outside of our hospital.

In summary, a well-designed e-prescribing system, such as ATEMM, can reduce prescribing safety errors and improve formulary compliance. Characteristics of a well-designed e-prescribing system include:

1. Early end-user engagement in the design and implementation process;
2. User-friendly user-interaction and user interface;
3. Fields allowing selection of abbreviations should include only approved abbreviations;
4. So as not to limit prescribing freedom, fields should allow free text options wherever possible; and
5. The system should indicate which medications are "on-formulary" based on a patient's insurance, but should allow non-formulary prescribing.

This study supports prior observations of the impact of e-prescribing on prescription error rates and formulary compliance, and expands current understanding of e-prescribing benefits by demonstrating extension to safety-net organizations and populations.

Tables and Figures

Table 1. Changes in Prescribing Errors, 2011 vs. 2013+2014 Combined

	2011	2013 + 2014 Averaged	Relative Change of 2011 vs. Average of 2013 + 2014	P-Value
Total Errors				
# of prescriptions	142,249	147,915	4.0%	
# with errors	5,261	3,085	-41.4%	
% with errors	3.7%	2.1%	-43.6%	<0.0001
Safety Errors				
# with safety errors	2,443	1,237	-49.4%	
% with safety errors	1.7%	0.8%	-51.3%	<0.0001
Formulary Non-Compliance				
# with formulary non-compliance	685	226	-67.0%	
% with formulary non-compliance	0.5%	0.2%	-68.3%	<0.0001

Table 2. Prescribing Error Details, 2011 vs. 2013 + 2014 Average

Error Type	2011 Errors (#)	2011 Errors (% of Total)	2013 + 2014 Averaged Errors (#)	2013 + 2014 Averaged Errors (% of Total)	Relative Change in Errors, 2011 vs. Average of 2013 + 2014	P-Value
Safety Errors						
Dose Error	1,124	35.9	725	49.6	-35.5	<0.001
Drug Clarification	398	12.7	25	1.7	-93.7	<0.001
Duplicate Therapy	463	14.8	112	7.7	-75.8	.001
Inappropriate Frequency of Administration	380	12.1	242	16.6	-36.3	0.002
Illegible Prescription	61	2.0	46	3.1	-24.6	0.11
Inappropriate Route of Administration	11	0.4	9	0.6	-18.2	0.32
Prohibited Abbreviation	6	0.2			N/A	No comparison possible
Other Intervention			59	4.0	N/A	No comparison possible
Total Safety Errors	2,443		1,218			
Formulary Non-Compliance	685	21.9	244	16.7	-64.4	<0.001
Total	3,128		1,462			

Table 3. Pharmacist Time and Cost Addressing Prescription Errors, 2011 vs. 2013 + 2014 Average

	2011	2013 + 2014 Average	Absolute Change	Relative Change
Total Errors				
Hours	350	175	-175	
Cost	$19,272	$9,643	-$9,629	-50.0%
Safety Errors				
Hours	280	149	-130	
Cost	$15,379	$8,204	-$7,175	-46.7%
Formulary Non-Compliance				
Hours	70	26	-45	
Cost	$3,893	$1,432	-$2,461	-63.2%

Figure 1. Percent of Prescriptions with Any Error, 2011 vs. 2013 + 2014 Average

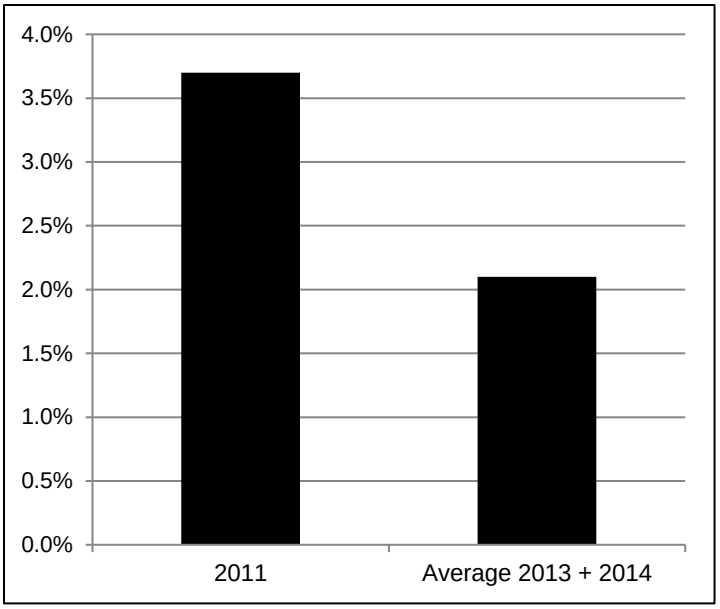


Figure 2. Percent of Prescriptions with Safety Error, 2011 vs. 2013 + 2014 Average

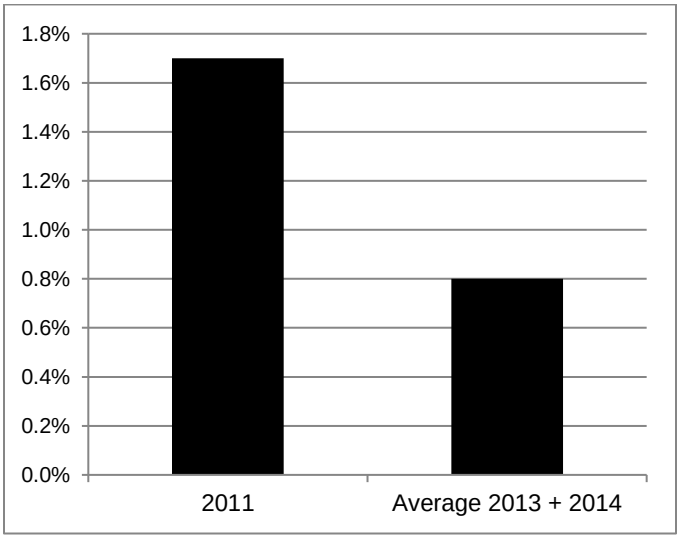


Figure 3. Percent of Prescriptions with Formulary Non-Compliance, 2011 vs. 2013 + 2014 Average

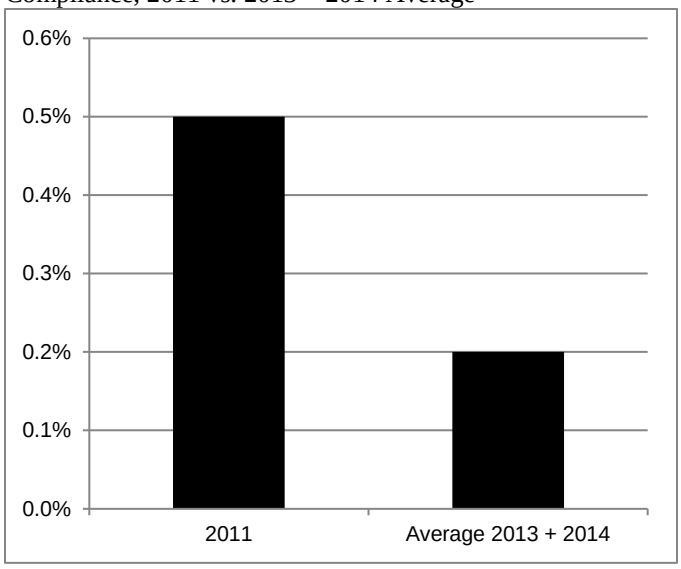


Figure 4. Annual Pharmacist Hours Addressing Prescription Errors, 2011 vs. 2013 + 2014 Average

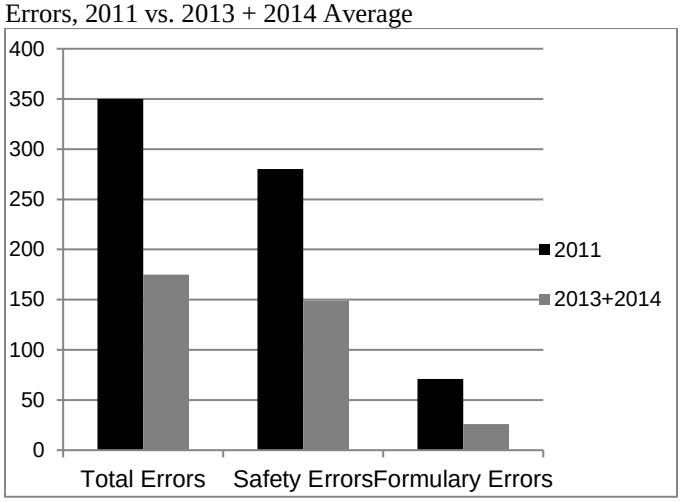
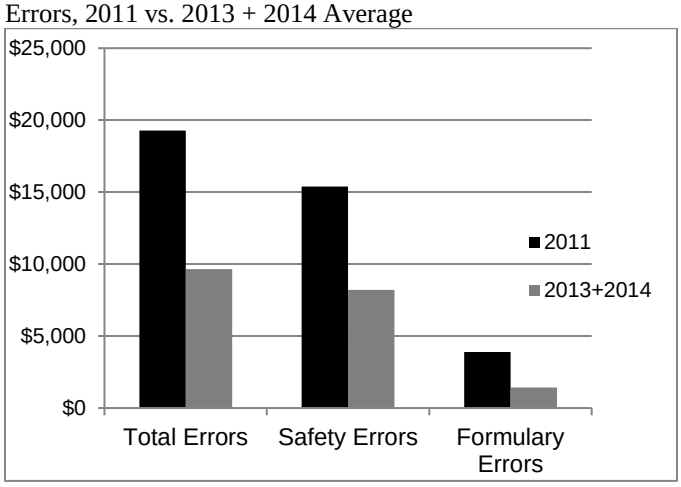


Figure 5. Annual Pharmacist Costs Addressing Prescription Errors, 2011 vs. 2013 + 2014 Average



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