Electronic Prescribing Improves Medication Safety in Community-Based Office Practices

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BACKGROUND: Although electronic prescribing (e-prescribing) holds promise for preventing prescription errors in the ambulatory setting, research on its effectiveness is inconclusive.

OBJECTIVE: To assess the impact of a stand-alone e-prescribing system on the rates and types of ambulatory prescribing errors.

DESIGN, PARTICIPANTS: Prospective, non-randomized study using pre-post design of 15 providers who adopted e-prescribing with concurrent controls of 15 paper-based providers from September 2005 through June 2007.

INTERVENTION: Use of a commercial, stand-alone e-prescribing system with clinical decision support including dosing recommendations and checks for drug-allergy interactions, drug-drug interactions, and duplicate therapies.

MAIN MEASURES: Prescribing errors were identified by a standardized prescription and chart review.

KEY RESULTS: We analyzed 3684 paper-based prescriptions at baseline and 3848 paper-based and electronic prescriptions at one year of follow-up. For e-prescribing adopters, error rates decreased nearly sevenfold, from 42.5 per 100 prescriptions (95% confidence interval (CI), 36.7–49.3) at baseline to 6.6 per 100 prescriptions (95% CI, 5.1–8.3) one year after adoption ($p<0.001$). For non-adopters, error rates remained high at 37.3 per 100 prescriptions (95% CI, 27.6–50.2) at baseline and 38.4 per 100 prescriptions (95% CI, 27.4–53.9) at one year ($p=0.54$). At one year, the error rate for e-prescribing adopters was significantly lower than for non-adopters ($p<0.001$). Illegibility errors were very high at baseline and were completely eliminated by e-prescribing (87.6 per 100 prescriptions at baseline for e-prescribing adopters, 0 at one year).

CONCLUSIONS: Prescribing errors may occur much more frequently in community-based practices than previously reported. Our preliminary findings suggest that stand-alone e-prescribing with clinical decision support may significantly improve ambulatory medication safety.

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INTRODUCTION

Health information technology (HIT), particularly electronic prescribing (e-prescribing), are potentially powerful tools for improving safety.[1] Large national policy forces to improve HIT adoption include $48 billion in the federal stimulus package.[2] Evaluating the use of e-prescribing for improving ambulatory medication safety is important given the high rate of ambulatory prescribing errors. A study of four academic affiliated adult primary care practices in Boston, MA, found errors in 7.6% of prescriptions, with nearly half having potential for harm.[3]

E-prescribing systems can either be stand-alone or integrated into an electronic health record (EHR). Integrated e-prescribing is generally viewed as the ideal because it increases patient information availability at the time of prescribing. However, the effect on safety of stand-alone systems, which are generally easier to implement and may represent an important option for providers, has not been described sufficiently.[4]

Multiple inpatient studies have shown that e-prescribing systems, particularly homegrown systems, can reduce prescribing errors and their harm.[1,5,6] In the ambulatory setting, fewer studies have measured the effect of e-prescribing on safety and results have been inconclusive.[3,7–10] For example, in a four practice study in Boston, e-prescribing with basic clinical decision support (CDS) did not reduce rates of prescribing errors.[3] Reasons for the lack of conclusive effectiveness demonstrated in the outpatient setting may include: 1) commercial systems are more common than homegrown systems and may have fewer iterative refinements 2) less technical support is generally available for individual users; 3) CDS may be less developed; 4) implementation practices are diverse; and 5) fewer studies have been performed.

Understanding the effects on safety of a commercially available stand-alone e-prescribing system used by community-based providers will be informative for future efforts promoting e-prescribing adoption. It is important to target the substantial national funds on effective and sustainable systems. As of 2004–2005, fewer than 25% of physicians in the ambulatory setting reported that e-prescribing systems were available in their practice.[11–13]

We undertook this study to assess the effects of a commercially available stand-alone e-prescribing system on ambulatory medication errors in solo and small group practices.

METHODS

Study Design

We conducted this IRB approved, prospective study of 30 ambulatory care providers using pre-post design with concurrent controls. We analyzed paper prescriptions at baseline and e-prescriptions at one year for 15 e-prescribing adopters and paper prescriptions at baseline and one year for 15 non-adopters.

Definitions

The Institute of Medicine defines medication errors as any error in the medication use process (prescribing, transcribing, dispensing, administering, and monitoring).[14] For this study we focused on prescribing errors only. An example of a prescribing error was ordering a medication but omitting the quantity. Near misses were potentially harmful errors that were intercepted or reached the patient but did not result in harm. An example was prescribing amoxicillin to a patient with a known allergy who took the medication without experiencing a reaction. Adverse drug events (ADEs) were injuries from a medication, a subset of which were associated with errors and defined as preventable. Error counts did not include rule violations, which were failures to follow strict prescribing rules that were unlikely to result in harm. Failure to write "po" for a medication only taken orally is an example.

Sites

We studied 12 adult primary care practices in the predominantly rural and suburban Hudson Valley region of New York from September 2005 to June 2007. Practice physicians were members of the Taconic Independent Practice Association (Taconic IPA), a not-for-profit organization. A letter was sent to members in May 2005 detailing incentives for adopting stand-alone e-prescribing or e-prescribing integrated into an EHR. This letter also invited providers to participate in a research study and provided discounts on EHR licenses as an incentive.

Practices ranged in size from 1–7 providers, and none were affiliated with an academic medical center. All providers used paper prescriptions at baseline. Six practices with 15 providers adopted e-prescribing and six practices with 15 providers did not adopt e-prescribing. None of the non-adopters started and then stopped using e-prescribing.

Electronic Prescribing Tool

The intervention was a web-based commercially available stand-alone e-prescribing system with CDS including alerts for drug allergies, drug-drug interactions, duplicate drug therapies, incorrect drug frequencies, incorrect dosing, and pregnancy and breastfeeding contraindications. Providers had access to an electronic reference guide for dosing recommendations. The system checked for insurance eligibility and formulary compliance. Prescriptions could be sent to pharmacies electronically.

Data Collection and Review

Prescription Collection. At baseline and one year, we collected carbon copies of handwritten and downloads of electronic prescriptions written by providers over a two-week period. We obtained a minimum of 75 prescriptions on 25 patients per provider, extending data collection if necessary. We limited review to three prescriptions per patient to minimize patient clustering of errors. During data collection periods, we removed non-duplicate prescription pads.

Prescription Review. One physician (R.K) trained nurse and pharmacist reviewers in an identical manner using extensively utilized standardized methodology.[3,15–18] This included review of error definitions, assessment of legibility, and review of test and actual cases. A prescription was considered illegible if it could not be deciphered or could easily be misinterpreted. Two data collectors reviewed and discussed cases initially, after which R.K. observed both separately and remained available for questions. Methodology included error classifications, rule violation classifications, and ADE trigger drugs.[15]

We determined inter-rater reliability by randomly sampling 2% of the data. Inter-rater agreement for overall error and type of error between two research nurses was 1.0 and between one research nurse and one research pharmacist was 0.81 indicating very good to excellent agreement.

Chart Review. The research nurse performed ambulatory chart reviews whenever a suspected near miss was noted or when a drug often used to treat an ADE was prescribed to determine any sequelae including an ADE.

Physician Event Review and Classification. Two physicians independently reviewed all suspected near misses and ADEs including illegible prescriptions. Physician reviewers were blinded to the prescribing method of the provider. Confirmed ADEs and near misses were rated on preventability using a 5-point Likert scale and attribution using the Naranjo algorithm.[19] Severity of ADEs was rated using a 4-point Likert scale. Inter-rater agreement for the presence of prescribing errors and near misses was 0.97 and 0.95 (p-value<0.001), demonstrating excellent agreement. We developed a classification scheme for the types of CDS available and determined whether basic or advanced CDS could have prevented the error. We examined the subset of preventable errors detected among both adopters of e-prescribing and non-adopters that remained at one year. Illegibility errors were excluded from this analysis but were all eliminated by basic CDS.

Statistical Analysis. We compared error rates per 100 prescriptions of 1) providers adopting e-prescribing and non-adopters at baseline, 2) providers adopting e-prescribing at baseline and one year, 3) non-adopters at baseline and one year, and between 4) providers adopting e-prescribing and non-adopters at one year using mixed effects Poisson regression, to adjust for clustering, using provider as the unit of analysis. We assumed an independent correlation structure for all Poisson models. We calculated 95% Poisson confidence intervals (CIs) with cluster robust standard errors for the rates. We also compared presence of any error per prescription using logistic mixed effects models, adjusting for clustering with provider as the unit of analysis. We used SAS for PC version 9.1 (SAS Institute, Inc., Cary, NC) to estimate, kappa statistics, chi-square, and t-tests, and Stata 10 (StataCorp, College Station, TX), to estimate mixed–effects Poisson and logistic models, and to calculate 95% Poisson and logistic confidence intervals with clustered robust standard errors.

RESULTS

Prescriber Characteristics

We studied a total of 30 providers (Table 1). Adopters and non-adopters did not differ significantly in gender, degree or years since graduation.

All providers who adopted e-prescribing and 11 non-adopters practiced at one office location each, while 4 non-adopters practiced at 2 sites. The e-prescribing system was web-based and could be utilized at multiple office locations for no additional licensing cost. Eight paper-based offices were rural and 11 were suburban, while 10 e-prescribing offices were rural and 5 were suburban (p=0.15).

Patient Characteristics

For paper-based providers, 1054 of 2761 (38%) unique patients seen during the baseline period received prescriptions, and 963 of 2543 (38%) unique patients seen at one year received prescriptions. For e-prescribing adopters, 1273 of 2968 (43%) unique patients seen during the baseline period received paper prescriptions and 1598 of 2439 (66%) unique patients seen at one year received e-prescriptions (Table 2). Patients of adopters were older than patients of non-adopters (p<0.001).

Table 1. Characteristics of Healthcare Providers

	All providers	Non-adopters[a]	Adopters[b]
	N=30	N=15	N=15
Female	12 (40%)	5 (33%)	7 (47%)
Years since graduation mean (SD)	18 (8)	20 (10)	15 (6)
Degree			
MD or DO	24 (80%)	12 (80%)	12 (80%)
Nurse practitioner	2 (7%)	1 (7%)	1 (7%)
Physician assistant	4 (13%)	2 (13%)	2 (13%)
Specialty (for MD or DO)	N=24	N=12	N=12
Internist	9 (38%)	5 (42%)	4 (33%)
Family practitioner	15 (63%)	7 (58%)	8 (67%)

[a]*Represents characteristics of providers who did not adopt e-prescribing*
[b]*Represents characteristics of providers who did adopt e-prescribing*

Baseline Error Rates

We reviewed a total of 3684 paper-based prescriptions at baseline. Both groups of providers had high error rates (42.5 per 100 prescriptions for adopters and 37.3 per 100 prescriptions for non-adopters, p=0.20) (Table 3). Among adopters, 35% of prescriptions contained at least one error, and among non-adopters, 29.8% of prescriptions contained at least one error (p=0.38). Rates of near misses were low. There were no preventable ADEs in either group.

Rates of Errors for Providers Adopting E-prescribing at Baseline and at One Year

We reviewed a total of 3848 prescriptions at follow-up, of which 2305 were electronic prescriptions. E-prescribing significantly decreased prescribing error rates from 42.5 to 6.6 errors per 100 prescriptions (p<0.001) (Table 3). There was no significant change in near misses. There were 0.04 preventable ADEs per 100 prescriptions at follow-up, compared with zero at baseline. (p=>0.99)

Rates of Errors for Non-adopters at Baseline and at One Year

There was no statistically significant change in error rates among non-adopters (p=0.54). There was a higher rate of near misses at one year (2.7 vs. 1.01 near misses per 100 prescriptions) (p<0.001) (Table 3). There were 0.26 preventable ADEs per 100 prescriptions at one year compared with zero at baseline (p=0.046).

Comparison in Error Rates for Providers Adopting E-prescribing and for Non-Adopters at One Year

E-prescribing adopters had significantly lower rates of errors and near misses than non-adopters at one year (6.6 vs. 38.4 errors per 100 prescriptions (p<0.001) and 1.3 vs. 2.7 near misses per 100 prescriptions (p<0.001)) (Table 3). Rates of preventable ADEs trended lower among adopters (0.04 vs. 0.26 per 100 prescriptions (p=0.26)).

Types of Prescribing Errors

E-prescribing variably decreased all types of prescribing errors (Table 4). At baseline, the most common errors made by adopters were inappropriate abbreviations and duration errors. Examples are shown in Table 5. Duration and directions errors were most frequent among adopters at follow-up.

Illegibility Errors

E-prescribing eliminated all illegibility errors. At baseline, there were 87.6 illegibility errors per 100 prescriptions among adopters, with illegible physician signature and strength or strength units the most frequent type.

Rule Violations

E-prescribing eliminated almost all types of rule violations. At baseline, there were 67.6 rule violations per 100 prescriptions

Table 2. Patient Characteristics

		Patients with prescriptions			Patients without prescriptions			All patients		
		Non-adopters[a]	Adopters[b]	p-value	Non-adopters[a]	Adopters[b]	p-value	Non-adopters[a]	Adopters[b]	p-value
Baseline	N	1054	1273		1707	1695		2761	2968	
	Age: mean (SD)	53 (18)	56 (18)	<0.001	53 (18)	57 (18)	<0.001	53 (18)	57 (18)	<0.001
	Female gender	640 (61%)	790 (62%)	0.51	1089 (64%)	976 (58%)	<0.001	1729 (63%)	1763 (59%)	0.01
One Year	N	963	1598		1580	841		2543	2439	
	Age: mean (SD)	53 (18)	57 (20)	<0.001	53 (18)	56 (20)	0.003	53 (18)	56 (20)	<0.001
	Female gender	595 (62%)	962 (60%)	0.43	940 (60%)	461 (55%)	0.025	1535 (60%)	1423 (58%)	0.15

[a]*Represents patients of providers who did not adopt e-prescribing*
[b]*Represents patients of providers who adopted e-prescribing*

among adopters. Only route omitted, PRN without indication and dose units omitted remained after e-prescribing adoption.

Prescribing Errors and the Impact of Clinical Decision Support

At one year, e-prescribing adopters had significantly fewer errors judged as preventable by advanced and by basic CDS than non-adopters (Table 3). Among e-prescribing adopters, a larger proportion of the remaining errors were judged preventable with advanced CDS (Table 6).

DISCUSSION

We found a nearly sevenfold reduction in error rates among community-based ambulatory providers using a commercially available stand-alone e-prescribing system, while error rates among non-adopters remained high.

Our study is one of the first to demonstrate a reduction in prescribing errors in ambulatory solo and small group community practices, where e-prescribing adoption and usage has lagged.[20] The ability to demonstrate significant reductions in errors in this setting is important as an estimated 2.6 billion drugs are provided, prescribed, or continued at ambulatory

Table 3. Error Rates for Both Groups of Providers

	N			Rates per 100 Prescriptions (95% CI) [e]		
Baseline error rates for providers adopting e-prescribing and for non-adopters						
	Total	Non-adopters[a]	Adopters[b]	Non-adopters[a]	Adopters[b]	p-value[d]
N	–	–	–	1783	1901	–
Medication errors[c]	1473	665	808	37.3 (27.6, 50.2)	42.5 (36.7, 49.3)	0.20
Rule violations	2316	1030	1286	57.8 (43.7, 76.4)	67.7 (54.4, 84.2)	0.34
Near misses	46	18	28	1.01 (0.7, 1.4)	1.47 (0.8, 2.7)	0.42
Rates of errors for providers adopting e-prescribing at baseline and at one year						
	Total	Pre	Post	Pre	Post	p-value[d]
N	–	–	–	1901	2305	–
Medication errors[c]	959	808	151	42.5 (36.7, 49.3)	6.6 (5.1, 8.3)	<0.001
Rule violations	1388	1286	102	67.7 (54.4, 84.2)	4.4 (3.1, 6.3)	<0.001
Near misses	58	28	30	1.47 (0.8, 2.7)	1.30 (0.7, 2.5)	0.61
Rates of errors for non-adopters at baseline and at one year						
	Total	Pre	Post	Pre	Post	p-value[d]
N	–	–	–	1783	1543	–
Medication Errors[c]	1257	665	592	37.3 (27.6, 50.2)	38.4 (27.4, 53.9)	0.54
Rule violations	1902	1030	872	57.8 (43.7, 76.4)	56.5 (41.8, 76.5)	0.69
Near misses	60	18	42	1.01 (0.7, 1.4)	2.7 (1.8, 4.0)	<0.001
Comparison in error rates for providers adopting e-prescribing and for non-adopters at one year						
	Total	Non-adopters[a]	Adopters[b]	Non-adopters[a]	Adopters[b]	p-value[d]
N	–	–	–	1543	2305	–
Medication errors[c]	743	592	151	38.4 (27.4, 53.9)	6.6 (5.1, 8.3)	<0.001
Rule violations	974	872	102	56.5 (41.8, 76.5)	4.4 (3.1, 6.3)	<0.001
Near misses	72	42	30	2.7 (1.8, 4.0)	1.3 (0.7, 2.5)	0.04
Prescribing errors that remained at one year which were judged preventable with clinical decision support						
Advanced alerts[f]	404	334	70	21.7 (12.0, 37.2)	3.0 (2.2, 4.2)	<0.001
Basic alerts[g]	203	160	43	10.4 (7.9, 15.2)	1.9 (1.2, 2.9)	<0.001

[a]*Represents providers who did not adopt e-prescribing*
[b]*Represents providers who did adopt e-prescribing*
[c]*Excluding illegibility errors and rule violations*
[d]*Calculated using mixed-effects Poisson regression adjusting for clustering, using provider as the unit of analysis.*
[e] *Poisson confidence intervals using cluster robust standard errors*
[f] *Medication errors preventable with advanced clinical decision support*
[g] *Medication errors preventable with basic clinical decision support*

Table 4. Types of Prescribing Errors at Baseline & One Year for E-prescribing Adopters

	Number (%)			Rate per 100 prescriptions (95% CI)[b]	
	Total	Pre	Post	Pre	Post
				N=1901	N=2305
				Rate (95% CI)[b]	Rate (95% CI)[b]
Medication errors[a] (N)	959	808	151	42.5 (36.7, 49.3)	6.6 (5.1, 8.3)
Type of error					
Inappropriate abbreviation[c]	243 (15)	242 (16)	1 (0.5)	12.7 (11.2,14.4)	0.04 (0.001, 0.2)
Dose error[c]	61 (4)	51 (3)	10 (5)	2.7 (2.0, 3.5)	0.4 (0.2, 0.8)
Frequency error[c]	64 (4)	45 (3)	19 (9)	2.4 (1.7, 3.2)	0.8 (0.5, 1.3)
Duration error[c]	228 (13)	188 (13)	40 (19)	9.9 (8.5, 11.4)	1.7 (1.2, 2.4)
Directions error[c]	160 (9)	120 (8)	40 (19)	6.3 (5.2, 7.5)	1.7 (1.2, 2.4)
Strength error	42 (3)	41 (3)	1 (0.5)	2.2 (1.5, 2.9)	0.04 (0.001, 0.2)
Amount error	28 (2)	25 (2)	3 (1)	1.3 (0.9, 1.9)	0.1 (0.03, 0.4)
Other errors[c]	93 (5)	82 (5)	34 (16)	4.3 (3.4, 5.3)	1.5 (1.0, 2.1)

[a]*Excluding illegibility errors and rule violations*
[b] *Poisson confidence intervals with cluster robust standard errors*
[c] *Significantly different pre-post rates (p<0.05)*

care visits and national efforts are directed at promoting ambulatory e-prescribing adoption.[21,22]

Our rates of baseline prescribing errors are higher than those previously reported and highlight the importance of studying this setting. In a study using the same methodology of four academic primary care clinics, the number of prescriptions containing at least one error was 7.6% compared to our rate of 29.8–35%. Our error rates might be higher for several reasons. We studied community-based providers who may have different support systems and prescribing patterns compared to academically affiliated providers. There might also be variations in patient complexity or practice characteristics.

Differences in e-prescribing systems, including workflow integration and level of CDS, may help explain the inconclusive effects of e-prescribing on outpatient medication safety to date.[3,7–10] However, some effectiveness has been shown in specific circumstances. For example, e-prescribing integrated into an EHR targeting potentially contraindicated medications in elderly patients reduced nonpreferred medication use.[9] Another e-prescribing application decreased drug-lab interactions through an abnormal laboratory result alert.[10] Finally, there was a decrease in warfarin drug interactions through an interaction alert in an integrated e-prescribing application.[8]

Table 5. Examples of Prescribing Errors and Near Msses

Errors and Near Misses
Medication Errors
Lortisone® cream (Betamethasone and Clotramizole cream) is prescribed without a frequency for application
Amoxicillin 500 mg is prescribed with length of treatment omitted
Ketoconazole 2% antifungal cream is prescribed with directions for use omitted
Rhinocort® Aqua® Nasal Spray (Budesonide nasal spray) is prescribed with frequency omitted
Near Misses
Relpax® (Eletriptan) is ordered with dose and frequency omitted
Hydrocodone 5/500 mg tablets are ordered as “1–2 tablets Q4-6 hr PRN pain” with maximum daily dose omitted
Ortho Evra® contraceptive patch (Ethinyl Estradiol and Norelgestromin contraceptive patch) instructions incorrectly written as “apply one patch monthly”
Lasix® (Furosemide) is ordered with strength omitted

An important question not addressed by this study is whether e-prescribing systems integrated in EHRs are as effective as stand-alone systems. Currently most e-prescribing is done within EHRs.[23] Integrated systems generally allow providers increased access to information at the time of prescription writing. However, stand-alone e-prescribing is generally less costly and easier to implement.[4] It is unknown which system is better suited to provider workflow.

The commercial e-prescribing system we studied included many features recommended by an expert panel on e-prescribing applications.[24] Features in commercial products, including levels of CDS, vary greatly, ranging from reactive alerts to more advanced features such as patient-specific dose checking. Of ten commercially available e-prescribing systems in 2002–2003, 64% had features classified as basic by an expert review panel and only 12% had the most advanced CDS.[23] Both basic and advanced CDS appear important for improving ambulatory medication safety in our study, but

Table 6. Remaining Errors Preventable with Advanced CDS

Type of Error	Paper	E-prescribing
	N (%)	N (%)
Medication errors judged to be preventable with advanced clinical decision support		
	1264	70
Inappropriate use of abbreviation	797 (63%)	–
Directions error	197 (15%)	36 (51%)
Length of treatment error	175 (14%)	20 (29%)
Dose error	27 (2%)	5 (7%)
Frequency error	24 (2%)	4 (5%)
Amount to be dispensed error	23 (2%)	3 (4%)
Other	21 (2%)	2 (3%)
Medication errors judged to be preventable with basic clinical decision support		
	9434	43
Illegible	8898 (94%)	–
Dose error	121 (1%)	4 (9%)
Strength error	108 (1%)	1 (2%)
Frequency error	99 (1%)	15 (35%)
Amount to be dispensed error	79 (1%)	–
Directions error	72 (1%)	4 (9%)
Length of treatment error	57 (1%)	19 (44%)

their potential is still under-realized. After e-prescribing adoption, preventable errors remained. This suggests that content or representation of CDS is insufficient. Providers report that currently available commercial e-prescribing CDS applications is poorly designed, does not add value and does not lead to modification of prescribing choices.[20]

The less serious prescribing errors and illegibility errors are worth studying for their potential impact on safety and their impact on efficiency. In a study by Grossman and colleagues, most physicians rated improved legibility as the greatest benefit of e-prescribing because they believed it reduced pharmacy errors in filling prescriptions and callbacks for clarification.[20] A study by Wang and colleagues also found that compared to paper prescribers, most e-prescribers reported having better information to reduce inefficiencies associated with pharmacy calls for potential safety problems.[25]

Providers who adopted e-prescribing in our study benefited from well-designed implementation and technical support as managed by MedAllies, a for-profit Health Information Service Provider.[26] This included routine monitoring of e-prescribing compliance and ongoing support to encourage 100% use. A recent study examining e-prescribing implementation and usage among 12 ambulatory practices showed that unsuccessful practices reported more difficulties with technical aspects of implementation and insufficient technical support.[27] Without extensive technical support, it is difficult to achieve high rates of use and subsequent improvements in medication safety. The importance of technical assistance has been recognized by the federal government, which is funding the Health Information Technology Extension Program for Regional Centers to provide technical support for providers adopting EHRs.[2]

Our study has several limitations. Although we attempted to ensure that prescribers used duplicate prescription pads, providers may have sometimes used non-duplicate prescriptions. This may have resulted in fewer paper prescriptions and account for the apparent increase in prescribing rates for adopters, as e-prescribing compliance was high and e-prescription retrieval was complete. Future studies should explicitly examine the effects of e-prescribing on prescribing rates.

We studied only 30 providers using a non-randomized design. Thus there may be differences between adopters and non-adopters not captured by our study. Providers were not blinded to the study's purpose and may have been extra careful when prescribing, making our results conservative estimates of true error rates. Our study was conducted in one geographic region among small, private physician practices, limiting generalizability. We also studied only one stand-alone e-prescribing system, however this system is a popular commercially available system incorporating many features recommended by an expert panel.[24] Future studies should be performed with more providers, at diverse sites, and with multiple systems.

We were also limited by our methodology to comment on preventable ADEs, as these are best detected by patient surveys.[3] Although it is likely that stand-alone e-prescribing systems are effective in reducing preventable ADEs, future studies should explicitly evaluate this question.

CONCLUSION

Ambulatory prescribing errors rates might be much higher than previously reported. E-prescribing had been shown to decrease errors in the inpatient setting, but its effect in the ambulatory setting has been unclear. This is one of the first studies to show that a commercially available, stand-alone e-prescribing system is effective in primary care practices, demonstrating a nearly seven-fold decrease in errors. Of note, there was good CDS in the e-prescribing system and extensive technical support for users. Findings from this study may inform policies promoting e-prescribing adoption in the ambulatory setting.

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