An unintended consequence of electronic prescriptions: prevalence and impact of internal discrepancies

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ABSTRACT

Many e-prescribing systems allow for both structured and free-text fields in prescriptions, making possible internal discrepancies. This study reviewed 2914 electronic prescriptions that contained free-text fields. Internal discrepancies were found in 16.1% of the prescriptions. Most (83.8%) of the discrepancies could potentially lead to adverse events and many (16.8%) to severe adverse events, involving a hospital admission or death. Discrepancies in doses, routes or complex regimens were most likely to have a potential for a severe event (p=0.0001). Discrepancies between structured and free-text fields in electronic prescriptions are common and can cause patient harm. Improvements in electronic medical record design are necessary to minimize the risk of discrepancies and resulting adverse events.

Medication-related errors are a common cause of morbidity among ambulatory patients, and electronic prescribing is widely considered to be the agent capable of stemming the tide of medication-related errors.[1–4] Electronic medical record (EMR) systems featuring e-prescribing capabilities are not without fault, however, and unintended consequences of their use are under increasing scrutiny.[5–12]

Electronic prescribing systems capable of providing advanced decision support have been identified as the most likely interventions to reduce the rates of adverse drug events (ADE; used hereafter to denote one or more adverse drug events).[2] These systems rely on calculations involving discrete data about a given prescription, such as dose and frequency information. Consequently, user interfaces of such systems impose restrictions on the values that could populate various fields in a prescription (eg, a drop-down menu with predefined frequencies). The more data that are available in a structured, computable format, the easier it is to implement advanced decision support capabilities. However, patients and prescribers frequently require auxiliary instructions, which modify, clarify or add to information on a prescription.[13] Such auxiliary instructions are common and are typically accommodated by means of a free-text field. The presence of a free-text field gives rise to the possibility that information entered there might be inconsistent with other parts of a prescription crafted by manipulating structured data fields.

Figure 1 shows two prescriptions with internal discrepancies generated by our EMR system. There are three lines of particular interest to this study: Rx, Sig, and Special Instructions. The Rx line typically contains medication name, strength amount and units, and drug form. The Sig line includes take amount and units, dose amount and units, route of administration, frequency (including PRN), and duration in days. A user manipulates structured fields in the EMR system to generate Rx and Sig lines. The Special Instructions line includes potentially detailed instructions and clarifications; it is generated by a free-text field. The differences between information contained in the Rx and Sig lines and contents of the Special Instructions line are the subject of this study.

The effect of these discrepancies on patient care is poorly understood. In this paper, we describe a study designed to quantify the prevalence of internal discrepancies between structured and free-text fields of individual electronic prescriptions and analyze the potential adverse events they could cause using the data collected from a local ambulatory EMR system.

METHODS

Design

We carried out a retrospective manual review of randomly selected electronic prescriptions generated in an internally developed ambulatory EMR system between January and March 2007.

Data sources

The ambulatory EMR deployed across Partners HealthCare is the Longitudinal Medical Record (LMR)—a Certification Commission for Health Information Technology (CCHIT)-certified internally developed system. Similarly to many other EMR, the LMR electronic prescribing module contains both structured fields, where the users are encouraged to select from a list of values, and a free-text field called 'Special Instructions'. A random selection of prescriptions generated in the LMR over the period from January to March 2007 was analyzed. No stratification was utilized in the randomization scheme.

Discrepancy classification

Based on a preliminary review of 1000 randomly selected prescription records, we identified 12 classes of discrepancies between the structured elements of the prescription and the free-text instructions. For each record, the following elements of the Rx and the Sig lines of a prescription were analyzed for

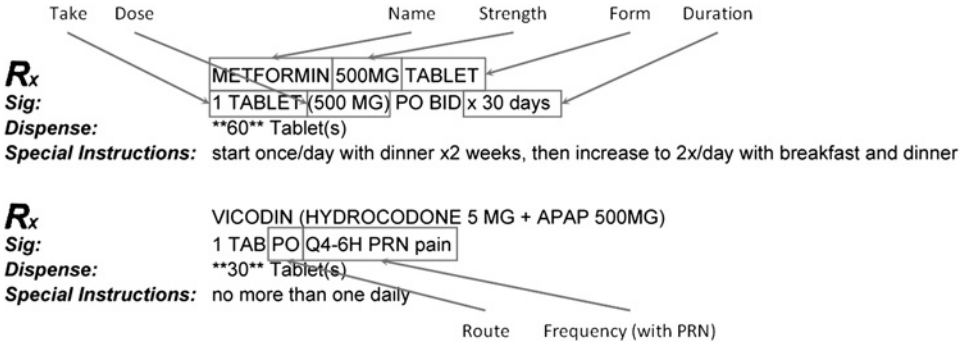

Figure 1 Examples of prescriptions with internal discrepancies. Manipulating structured data fields generates Rx and Sig lines. Typically occurring individual elements of these lines are labelled. 'Special Instructions' is a free-text field.

a discrepancy with the free-text instructions: medication name, route of administration, strength amount and units, form, dose amount and units, take amount and units, frequency (including PRN), duration in days, dispense amount, and dispense units. A user has to interact with a structured field (such as drop-down with allowable values) to generate each of these elements. Inconsistencies leading to internal discrepancy occur when information specified for a prescription component in one of the structured fields differs from the information provided for the same prescription component in the free-text 'Special Instructions' portion of the prescription. Upon reviewing a prescription record, there is frequently no reliable way to discern which of the two conflicting pieces of information is correct; it is only possible to detect a discrepancy.

Each prescription was independently reviewed by two pharmacists who established whether there was a discrepancy, classified the discrepancy, and assigned a level of severity for a potential ADE. When they disagreed, a re-review by a team composed of the original reviewers and an internist arrived at a consensus.

Potential ADE rating

For every prescription with a discrepancy, reviewers assessed the potential for an ADE based on the assumption that a pharmacist would fill the prescription as written with the original Special Instructions included verbatim. In assessing the potential ADE, reviewers considered a plausible worst-case scenario in which patient instructions would maximally deviate from what was intended by the prescriber. The reviewers considered potential ADEs stemming both from incorrect medications or correct medications taken incorrectly. Each prescription was rated as either having no potential for an ADE, potential for a mild to moderate ADE that would not require inpatient treatment, or potential for a severe ADE leading to a hospital admission or death. A set of rules was developed to aid reviewers in assigning ADE ratings in the most common scenarios; for example, one such rule is, 'For medications of non-narrow therapeutic range, excess in dose up to and including twofold increase is rated as mild/moderate. Excess in dose greater than twofold is rated as severe if clinically appropriate.'

Prescription discrepancies and high-risk medications

We hypothesized that medications known to carry a high risk of adverse events may also have a higher rate of internal prescription discrepancies. To test this hypothesis we determined the fraction of discrepancies for medications previously reported to be associated with a high rate of emergency department visits for ADE (warfarin, insulin, and digoxin)[14] compared with all other medications.

Statistical analysis

Summary statistics were constructed by using frequencies and proportions for variables. The kappa coefficient was calculated to assess the agreement between the reviewers. Fisher's exact test was used to compare fractions. All analyses were performed using SAS statistical software, version 9.1.

The study protocol was reviewed and approved by the Partners Human Research Committee and waived the need for informed consent. All data used in the study were completely de-identified.

RESULTS

A total of 410 558 outpatient electronic prescriptions were generated during the 3-month study period; free-text instructions were found in 187 602 (45.7%). Excluding prescriptions for durable medical equipment as well as those containing instructions with no potential for causing a discrepancy (eg, 'take as directed', 'take with food', 'no substitutions', and 'please call and make appt with MD'), 176 183 (42.9%) prescriptions contained free-text instructions that might potentially cause a discrepancy.

A random sample of 2914 prescriptions (86 out of the 3000 originally selected prescriptions that were written for non-medications, such as glucometer supplies, were excluded from further analysis) with free-text instructions was chosen to be manually examined. Independent reviewers agreed on whether or not a discrepancy between the free-text instructions and the structured information was present in 2602 (89.3%) records, constituting good agreement (κ=0.662, 95% CI 0.626 to 0.697). Among the records in which a discrepancy was identified by both reviewers, the agreement on the maximum severity of the possible ADE was 43.6% (κ=0.13, 95% CI 0.057 to 0.203). In the consensus rating, 470 (16.1%, 95% CI 14.7% to 17.3%) prescriptions were found to have at least one discrepancy, 79 prescriptions contained more than one discrepancy, and seven prescriptions contained three discrepancies each.

We identified 12 classes of discrepancies (table 1). The majority (29.2% of all prescriptions with discrepancies or 4.7% of prescriptions examined) belonged to the 'complex regimen' class. This class included free-text instructions that call for a dose that varies over different times of administration in the course of a day, alternate doses on different days of the week, dose escalations or tapers, and other scenarios distinct from the unchanging dose and frequency over the entire treatment course covered by the prescription. Some of the least common classes of discrepancies included drug name mismatch and quantity mismatch (0.2% and 0.4% of all discrepancies, respectively).

A large majority of prescriptions with discrepancies (394/470 or 83.8%, 13.5% of all prescriptions with special instructions, or approximately 5.8% of the total number of prescriptions) could lead to an ADE (table 2). Some of the causes of potential ADE included over or underdosing (the difference sometimes as high as 55-fold), incorrect route (eg, intravenous instead of intravaginal), or ignoring dose escalation or tapering. Of all prescriptions with discrepancies, 79 (16.8%) were judged to have the potential for an ADE severe enough to lead to a hospital

Table 1 Distribution by discrepancy class and examples of conflicting information

	Examples		Occurrence		
Discrepancy Class	**Sig fragment**	**Free-text instructions**	**N**	**% of examined**	**% with discrepancies**
Complex regimen	TID	TID ×1 week and then as needed	137	4.70	29.15
	Q6–8H	1 po tid×7d, then 1 po bid×7d, then q6–8 h PRN pain; take with food			
	QHS	Start with 40 mg a day for a week, if no muscle pain increase to 80 mg			
	QD	Take 2 tablets in AM and 1 tablet in PM			
	QD	80 mg po qod alternating with 40 mg			
	QD	Take 1 tab qd, except on monday and friday. Take 120 mg on monday and friday			
	QD	1 qd except sunday			
Dosage range expanded inappropriately	5MG take 1 tab Q4H PRN pain	Take 1–2 tablets every 4 h as needed for pain	76	2.61	16.17
	Coumadin 5MG take 1 tab QPM	1–3 tabs…adjusted as necessary for PT levels			
Frequency mismatch	Q8H	May take 1–2 q 4 h PRN pain	66	2.26	14.04
	TID	Take 30cc every 6 h as needed for pain			
	×1	1 daily			
PRN mismatch	10MG take 1 QHS	As needed for sleep short term only	58	1.99	12.34
	1 Application QD	Apply as often as needed for itching			
	5MG take 1 tab QHS	Take one tablet by mouth every night at bedtime as needed for sleep			
Dose mismatch	50MG take 1 tab QD	Take 1 1/2 tablets daily	58	1.99	12.34
	500MG take 1 tab as directed	Take 2 g (4 tablets) 1 h prior to your dental procedure			
	30 units QHS	Inject 25 units every night at bedtime			
Imprecise conversion of daytime and around-the-clock frequencies	TID	Take one tablet every 8 h as needed. Do not exceed 4 tablets in a day	22	0.75	4.68
	Q8H	Take 3× per day with meals			
	QID	Take every 6 h (with food) for 4 days. After that may take only as needed			
Frequency range extended inappropriately	2 Puffs Q4H	2 Puffs every 1–4 h as needed	19	0.65	4.04
	1 Application BID	Apply to affected area of legs qd–bid			
	QD	May use up to 5 times a day, PRN to affected area			
Route mismatch	OD	For left eye/use as directed	17	0.58	3.62
	JTUBE	Take PO not Jtube			
	PO	2 Drops in the ear four times a day for earwax			
	PO	Apply to scalp lesions for 15 min QD			
Dosage form mismatch	Lotion	Pt needs liquid version, NOT lotion	10	0.34	2.13
	Tablet	Swallow capsule whole			
	Tablet	20 cc bid for 10 days			
Duration mismatch	10 days	One tab po bid×7 days	4	0.14	0.85
	5 days	Apply to affected eye/s three times a day for 5–7 days			
Quantity mismatch	Dispense 250 MG	Dispense 10 pills	2	0.07	0.43
Drug name mismatch	Procardia	Procardia XL	1	0.03	0.21

Percentages represent a fraction of total prescriptions examined (n=2914) and a fraction of prescriptions with discrepancies (n=470).

admission and/or death. (The 79 prescriptions with discrepancies judged to have potential for a severe ADE were not the same as the 79 prescriptions with more than one discrepancy.)

Dose mismatch, route mismatch and complex regimen mismatch were the most likely to lead potentially to a severe ADE at the average rate of 23.6% (table 3). On the other hand, imprecise conversion of daytime and around-the-clock frequencies (eg, 'bid' vs 'every 12 hours') and dosage form mismatches were never deemed to have the potential for a severe ADE (p=0.0001 for the comparison with the highest risk mismatch types).

Discrepancies were particularly common among medications previously reported to carry the highest risk of ADE (warfarin, insulin, digoxin).[14] The rate of discrepancies that could potentially lead to patient harm in this medication group was 24.1% compared with 13.3% among the rest of the medications (p=0.03).

DISCUSSION

In this retrospective analysis of nearly 3000 electronic prescriptions, internal discrepancies between structured data and free-text instructions were found in one in six prescriptions. Whereas some were benign, many were not. If our results can be generalized, 53 prescriptions that contain discrepancies that could potentially lead to a hospital admission or death are being written using our EMR system every day.

Pharmacists are likely to be able to identify most of these discrepancies. However, in many cases the correct set of instructions (structured vs narrative part of the prescription) cannot be established with certainty. This situation is likely to lead to a phone call from the pharmacist to the prescriber, decreasing the efficiency of both healthcare providers and delaying the delivery of the medication to the patient. It could possibly lead to a medication error if the original prescriber cannot be reached and the covering provider cannot correctly identify the prescriber's intentions.

Particularly worrisome is our finding that internal discrepancies were more common among medications that had been found to have a higher-than-average risk of ADE (warfarin, insulin, and digoxin). Discrepancies could further augment the risk associated

Table 2 Distribution by potential for an ADE and sample prescriptions

PADE severity	Examples	Possible adverse event	Occurrence, N (%)
No PADE	PERCOCET 5 MG/325 MG (OXYCODONE 5 MG/ACETAMINOPHEN 325 MG) 5MG-325MG TABLET PO Sig: 1—2 TAB Q4H Special Instructions: Take every 4—6 h for pain	NA	76 (16.17)
	LUNESTA (ESZOPICLONE) 2MG TABLET PO Sig: 2 MG take 1 TABLET QHS PRN Special Instructions: Take 1 QHS PRN insomnia, may take 2 if needed	NA	
	WELLBUTRIN SR 150MG TABLET CR PO Sig: 1 Tablet(s) BID Special Instructions: start use 1 week prior to tobacco quit attempt. start at 1 tab po qd×3d, then bid	NA	
Mild or moderate PADE	Metrogel PO Sig: .75% AD Dispense: 45 Gram(s) Special Instructions: apply to face BID	Mild propylene glycol (component of Metrogel) poisoning; lack of efficacy for treated condition	315 (67.02)
	PREDNISONE 1MG TABLET PO Sig: QAM Special Instructions: 4 tablets PO qAM then taper as directed	Lack of efficacy for treated condition	
	HYDROCHLOROTHIAZIDE 25MG TABLET PO Sig: 25 MG take 1 TABLET QD Special Instructions: take 1/2 tab q day	Elevated blood pressure	
	AMOXICILLIN 875MG TABLET PO Sig: 875 MG take 1 TABLET BID Special Instructions: 2 tabs bid×10 days	Lack of efficacy for treated condition	
Severe PADE	PREMARIN (CONJUGATED ESTROGENS) 25MG VIAL IV Sig: 25MG take 1 VIAL QD Dispense: 1 tube(s) Special Instructions: apply qhs for 2 weeks, then 2 times a week	Estrogen overdose (breast tenderness, drowsiness, fluid retention, changes in mental status)	79 (16.81)
	FLOVENT HFA 110 MCG INH Sig: 110 PUFF BID Dispense: 1 Inhaler(s) Special Instructions: Inhaler(s) 2 puffs bid	Steroid overdose (immunosuppression, hypertension, osteoporosis)	
	DermaSmoothe FS PO Sig: 1 QD Special Instructions: Use PRN scalp psoriasis	Steroid overdose (immunosuppression, hypertension, osteoporosis)	
	DEXAMETHASONE 4MG TABLET PO Sig: 40MG QAM Please take 40 mgs QAM once a week	Steroid overdose (immunosuppression, hypertension, osteoporosis)	

Percentages represent a fraction of prescriptions with internal discrepancies (n=470).
ADE, adverse drug event; PADE, potential adverse drug event.

with these medications, prescriptions for which are already associated with other types of errors.[15 16] On the other hand, it is possible that the underlying complexity of the prescriptions, particularly those for warfarin and insulin, predisposed both to ADE—as a result of the patient misunderstanding the prescription instructions—and internal discrepancies. Further research is needed to establish whether internal prescription discrepancies contribute to the high rate of ADE in these medications.

Errors are common in both handwritten and EMR-generated prescriptions. However, internal discrepancies are a special type of prescription error that is unique to EMR. Simply removing the free-text instruction field to solve this problem is not a viable option. The field is widely used—almost half of all prescriptions we examined contain free-text instructions—and most (over 80% in our dataset) provide information complementary to the structured data fields (eg, 'take with orange juice'), consistent

Table 3 Potential for an ADE by class of conflicting information

Discrepancy class	No PADE, N (%)	Mild/moderate PADE, N (%)	Severe PADE, N (%)
Complex regimen	6 (1.28)	100 (21.28)	31 (6.60)
Dosage range expanded inappropriately	4 (0.85)	66 (14.04)	6 (1.28)
Frequency mismatch	14 (2.98)	44 (9.36)	8 (1.70)
PRN mismatch	15 (3.19)	32 (6.81)	11 (2.34)
Dose mismatch	1 (0.21)	42 (8.94)	15 (3.19)
Imprecise conversion of daytime and around-the-clock frequencies	18 (3.83)	4 (0.85)	0
Frequency range extended inappropriately	8 (1.70)	9 (1.91)	2 (0.43)
Route mismatch	3 (0.64)	10 (2.13)	4 (0.85)
Dosage form mismatch	7 (1.49)	3 (0.64)	0
Duration mismatch	0	3 (0.64)	1 (0.21)
Quantity mismatch	0	2 (0.43)	0
Drug name mismatch	0	0	1 (0.21)

Percentages represent a fraction of total prescriptions examined.
ADE, adverse drug event; PADE, potential adverse drug event.

with previously published studies that show that structured and narrative data in the EMR are frequently complementary.[17]

As almost a third of affected prescriptions attempt to describe complex regimens, it is clear that providers desire to craft increasingly nuanced prescriptions. Faced with time-consuming interfaces for the entry of complex regimens, providers instead rely on free text to express their intentions efficiently. In another common scenario, the provider originally creates a prescription in which structured and free-text fields are synchronized but subsequently amends only one of them, leading to a discrepancy.

As previously published studies showed, e-prescribing is not a panacea against medication errors but rather a targeted intervention. Consequently, the rate of medication errors in areas not specifically targeted by EMR design is not reduced.[18] Furthermore, poor design and/or implementation of EMR can even increase error rates.[5 7 19] Our findings lend further support to this paradigm.

Providers need to be aware that their e-prescribing tools may create an opportunity for crafting a conflicting prescription and therefore must pay close attention to the output. There is a clear role for user training in raising awareness of this problem. Pharmacists who call prescribers for clarifications when trying to interpret the discrepancies should insist on getting an amended version, helping to ensure that the original electronic record does not retain erroneous data ready for subsequent re-transmission at the click of a button.[20] However, it falls to EMR designers to guard against internal discrepancies.[21 22] The highly structured data input needed to meet the requirements of advanced decision support must coexist with free-text instructions to accommodate highly expressive prescriptions. Potential solutions will be likely to encompass measures ranging from user interface improvements[23] to natural language processing-based decision support.

This study has several limitations. The data came from a single ambulatory EMR and may not be representative of other e-prescribing systems. However, the majority of widely used commercial, internally developed and open-source EMR systems informally reviewed by the authors exhibit a similar combination of default prescribing interfaces geared toward basic prescriptions, elements of structured data capture (separate fields, drop-down menus, default values), and a free-text field, making such systems susceptible to internal discrepancies. The generalizability of our findings is further confirmed by a previously published smaller study at a Veterans Administration hospital that showed a similar (5.3%) rate of errors among 500 prescriptions with a narrative component.[24] The inter-reviewer agreement on the presence of discrepancies, although good, was less than expected; probably due to the complexity of the underlying data. The inter-reviewer agreement on the severity of possible ADE was poor, limiting the interpretation of the data.

CONCLUSIONS

Internal discrepancies are highly prevalent in electronic prescriptions and can increase the likelihood that a potentially severe ADE may occur despite provider and pharmacy review. They are particularly common among medications associated with a high risk of ADE. Electronic prescribing tools must take steps to safeguard against internal discrepancies.

Competing interests None.

Ethics approval This study was conducted with the approval of the Partners HealthCare Institutional Review Board.

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