

Prescription Errors and Outcomes Related to Inconsistent Information Transmitted Through Computerized Order Entry

A Prospective Study

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Background: Although several types of computerized provider order entry (CPOE)-related errors may occur, errors related to inconsistent information within the same prescription (ie, mismatch between the structured template and the associated free-text field) have not been described, to our knowledge. We determined the nature and frequency of such errors and identified their potential predictive variables.

Methods: In this prospective study, we enrolled pharmacists to report prescriptions containing inconsistent communication over a 4-month period at a tertiary care facility. We also electronically retrieved all prescriptions written during the study period containing any comments in the free-text field and then randomly selected 500 for manual review to determine inconsistencies between free-text and structured fields. Of these, prescriptions without inconsistencies were categorized as controls. Data on potentially predictive variables from reported and unreported errors and controls were collected. For all inconsistencies, we determined their nature (eg, drug dosage or administration schedule) and

potential harm and used multivariate logistic regression models to identify factors associated with errors and harm.

Results: Of 55 992 new prescriptions, 532 (0.95%) were reported to contain inconsistent communication, a rate comparable to that obtained from the unreported group. Drug dosage was the most common inconsistent element among both groups. Certain medications were more likely associated with errors, as was the inpatient setting (odds ratio, 3.30; 95% confidence interval, 2.18-5.00) and surgical subspecialty (odds ratio, 2.45; 95% confidence interval, 1.57-3.82). About 20% of errors could have resulted in moderate to severe harm, for which significant independent predictors were found.

Conclusions: Despite standardization of data entry, inconsistent communication in CPOE poses a significant risk to safety. Improving the usability of the CPOE interface and integrating it with workflow may reduce this risk.

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SEVERAL STUDIES HAVE FOUND that computerized physician order entry (CPOE) systems reduce medication errors and overall patient harm.¹⁻⁴ However, computerization may introduce new error pathways.⁵⁻¹⁰ Errors facilitated by CPOE have received increasing attention in the literature, yet the true frequency of the problem is unknown.^{9,11,12} Most medication errors are related to the ordering process,¹³ and many types of CPOE-related errors have been described in recent years.⁵⁻¹⁰ For instance, a study using both qualitative and quantitative methods to study house staff interaction with a CPOE system at a tertiary care facility identified 22 different types of medication errors, including fragmented CPOE displays and inflexible ordering formats.⁹

To our knowledge, order entry errors related to inconsistent information within the same prescription have not been described.

For instance, even though CPOE standardizes details of order entry through use of structured templates, clarifications or non-standard specifications may still be entered through a free-text comment field. Narrative instructions in the free-text field have

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advantages in highly structured order entry forms¹⁴ because they allow flexibility for providers to enter clarifications regarding timing, dosage, or route of administration. The flexibility, however, can lead to discrepancies between the elements selected through the structured template and the provider's free-text comments (**Figure 1**). For example, inconsistent communication occurs when the provider selects "Warfarin 10 mg orally every day" through the template but in the comment field writes "Take 7.5 mg a

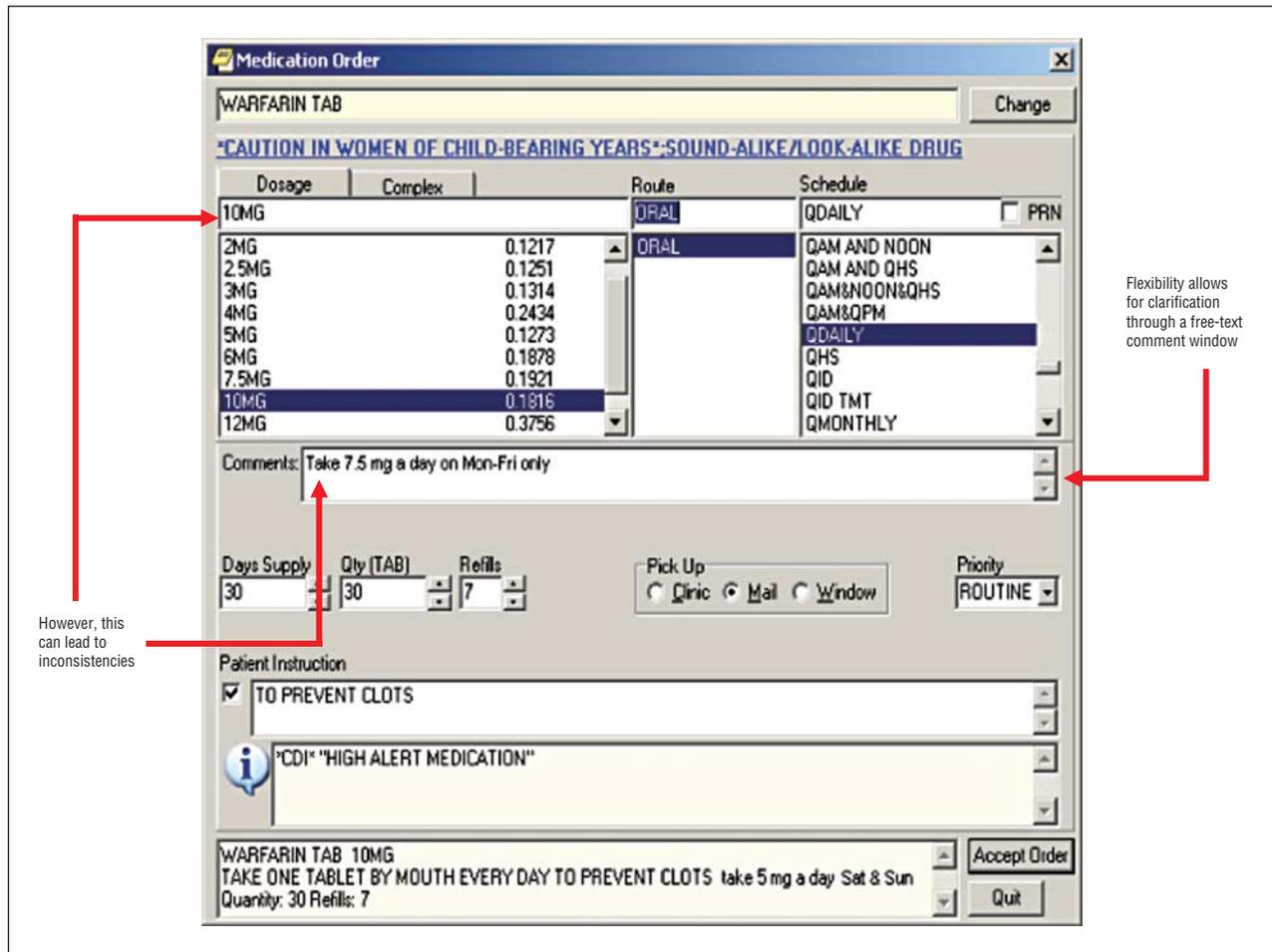


Figure 1. A screenshot of the computerized provider order entry interface showing structured entry and free-text window.

day on Monday-Friday only.” Because poor communication is an often-cited preventable factor in adverse events,¹⁵ it warrants further characterization of inconsistencies. While the pharmacist may know how to resolve the inconsistency, the free-text comments are printed on the label of the dispensed medication, which may confuse or harm the patient.

In our study, we analyzed an advanced CPOE system for inconsistent communication, which we defined as occurring when there was discordance between information entered through the structured template and the free-text comment field. Our objectives were to (1) describe errors and potential harm of inconsistent communication occurring within prescriptions entered through an advanced CPOE system; and (2) identify predictive variables associated with inconsistent communication and potential harm in an advanced CPOE so as to identify safety improvements. This project serves as a model for safety and usability enhancement in advanced CPOE systems.

METHODS

The study was conducted at the Michael E. DeBakey Veterans Affairs Medical Center (MEDVAMC) in Houston, Texas, and approved by the local institutional review board and the MEDVAMC research and development committee. We prospectively evaluated prescriptions written between October 1,

2007, and January 31, 2008, for inconsistent communication using 2 methods: stimulated pharmacy reporting and electronic searches for prescriptions with comments followed by random reviews. Since 1998, MEDVAMC has used CPOE, which is integrated with the Computerized Patient Record System, part of the larger Veterans Information System Technology Architecture. Each facility can customize the CPOE locally to a limited extent, but the overall development and maintenance is carried out nationally. Clinical decision support including checking for allergies, drug-drug interactions, dosing, and price information is available. New providers receive CPOE training, and additional information is available through an institutional Web page. All orders are entered exclusively through CPOE by resident physician trainees, staff physicians, and other allied health providers in inpatient and outpatient settings using structured fields with the option to enter free-text comments (Figure 1). Inconsistent communication could potentially involve the following data elements of the structured fields: name of drug, dosage, administration route, schedule, administration time, days supplied, quantity, refills, and duration.

PHARMACY REPORTING

In our institution, orders are electronically transmitted to an in-house pharmacy, where they are processed by 1 of 45 pharmacists. In general, pharmacists use their judgment to correct noted errors in the prescription or call the ordering provider. Institutional protocol requires pharmacists to call a provider

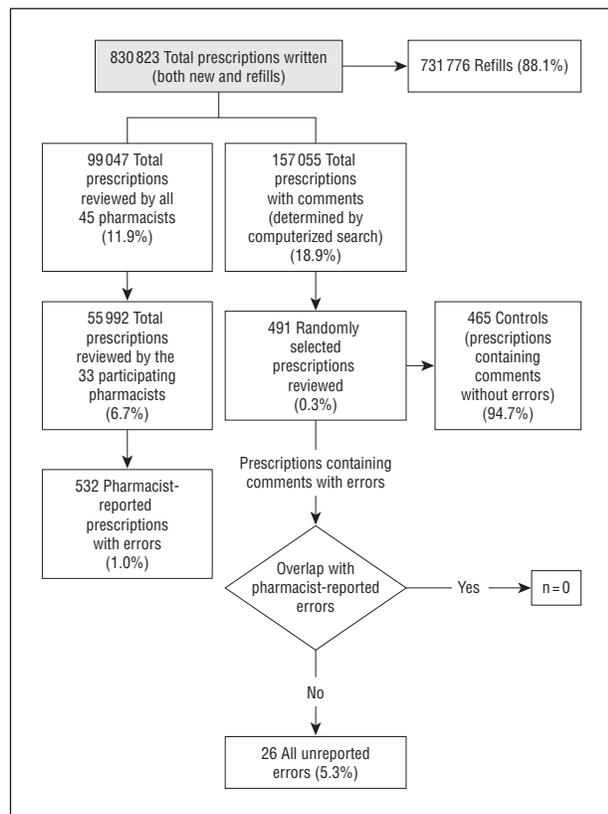


Figure 2. Study flowchart.

if the modification of an inconsistency involves a change in administration route, dose, schedule, the name of the ordered drug, or unclear comments. Prior to and throughout the study period, pharmacists were educated about the study, reminded to report prescriptions containing inconsistencies to the research team pharmacist, and offered a small financial incentive. Of 45 pharmacists, 33 agreed to report errors.

ELECTRONIC SEARCHES

Use of a single method (eg, stimulated self-reporting) has potential limitations in studies of medical errors.¹⁶ For instance, it cannot estimate error rate accurately.¹⁷ To overcome some of these disadvantages, we electronically searched for similar types of errors. We retrieved all prescriptions written during the study period containing comments in the free-text field and then randomly selected 500 for manual review to determine if they had inconsistent communication. Errors identified during manual review were cross-checked with those identified by pharmacists; if they were not present in the reported group, we considered them unreported errors. Prescriptions without errors from the latter sample were categorized as controls (Figure 2).

DATA COLLECTION

We developed a data collection form capturing the type of medication, setting (outpatient vs inpatient), nature of the inconsistency in errors (drug dosage, administration time, schedule, days supplied, quantity, refills, or duration), and potentially predictive variables (representing instances in which communication errors may be more likely). Potentially predictive variables for communication errors included prescriptions requiring a complex order (where providers should use an alternate complex order window for order entry), less frequently pre-

scribed (eg, restricted to certain specialties), medications considered “high-alert”¹⁸ (increased risk of causing patient harm if incorrectly used), and characteristics of the ordering providers. In cases of reported errors, pharmacists documented whether providers needed to be called and if the pharmacist filled the final prescription using information from the structured template, the free-text field, or in combination.

We used the Micromedex pharmaceutical classification system¹⁹ to group individual prescriptions into standardized drug classes. Two investigators (a physician and pharmacist) assigned harm categories by consensus using the Human Error Consequence Scale²⁰ after evaluating the results from the initial data collection. Harm categories were no error, inconvenience, very minor harm, minor harm, considerable harm, very serious harm, serious permanent damage, and immediate and inevitable death. The latter 4 categories were considered moderate to severe harm.

DATA ANALYSIS

We entered data into a Microsoft Access database (Redmond, Washington). A review of 80 random records validated quality of data entry. Of 5600 pieces of information collected in these 80 records, 5591 (99.8%) were found to be correct. Descriptive statistics were generated to characterize the inconsistent elements for all reported prescriptions. For prescriptions with and without inconsistent information, we compared the ordering provider characteristics (specialty and type of provider), setting of the error (eg, inpatient or outpatient), medication class (eg, antibiotics or analgesics), and other predictive variables (eg, less frequently prescribed or considered high alert). We also generated descriptive statistics for all harm categories. Univariate analysis was conducted using χ^2 and *t* tests. We used the Fisher exact test for categorical variables with 2 levels and the χ^2 test for categorical variables with more than 2 levels. We assessed statistical significance ($\alpha = .05$) for tests of predictors using the Wald χ^2 test.

Multivariate logistic regression models were used to identify factors associated with communication errors and moderate to severe harm. A generalized estimating equation approach in which errors were nested within providers allowed us to account for the potential correlation among errors. For the first predictive model using the entire data set, the outcome variable was whether the pharmacy record contained inconsistent communication. For the second model, based on the subset of records with errors, the outcome was whether the error resulted in moderate to severe harm vs minor to no harm. Predictor variables included all covariates significant in univariate testing. We fit the models using maximum likelihood estimation and calculated odds ratios (ORs) and 95% confidence intervals (CIs). To ensure that the model had stable and precise estimates of ORs, variables with small numbers of patients with a given characteristic (eg, ordering providers listed as clinical support, clinical specialist, or unknown) were removed or combined (eg, geriatrics, other medicine, spinal cord injury, and psychiatry specialties were all combined as “other specialties” in the model to predict harm), and a final model was run using the remaining predictor variables. We used SAS version 9.1 (SAS Institute Inc, Cary, NC) to conduct all statistical analyses.

RESULTS

Of 55 992 new prescriptions processed and reviewed by the pharmacists in the study period, 532 were reported by pharmacists to contain inconsistent communication (0.95%). A computerized search of the 830 823 prescriptions written in our study period (which included both refills and new prescriptions) found 157 055 containing a comment in the free-text window (18.9%) (Figure 2). From the lat-

Table 1. Types of Inconsistent Communication Errors in Prescriptions Reported by Pharmacists^a

Type of Error	Frequency of Error Occurrence	Frequency of Pharmacist Contacting Provider	Only Free-Text Information Used for Final Prescription Fill	Both Free Text and Structured Template Used for Final Prescription Fill
Dosage	239 (44.9)	94 (39.3)	201 (84.1)	7 (2.9)
Schedule or schedule type	109 (20.5)	46 (42.2)	93 (85.3)	4 (3.7)
Administration time	66 (12.4)	7 (10.6)	62 (93.3)	1 (1.5)
Duration/stop time	130 (24.4)	7 (5.4)	128 (98.5)	1 (0.8)
Days' supply	1 (0.2)	0	1 (100)	0
Quantity	9 (1.7)	3 (33.3)	7 (77.8)	1 (11.1)
Route	17 (3.2)	7 (41.2)	16 (94.1)	0
Drug dispensed	3 (0.6)	1 (33.3)	2 (66.7)	0
Orderable item	59 (0.9)	4 (80.0)	3 (60.0)	0
Refills	0	0	0	0
Total errors, No. ^b	633	169 (26.7)	513 (81.0)	14 (2.2)
Total prescriptions with errors, No.	532	149 (28.0)	473 (88.9)	10 (1.9)

^aUnless otherwise indicated, data are reported as number (percentage) of prescription communication errors.

^bThe total frequency of error occurrence sums to more than 532, and the total percentage might be greater than 100% because each prescription could contain more than 1 type of error.

ter group, we randomly selected 500 for manual review and excluded 9 written for glucose-monitoring supplies. From the remaining 491 prescriptions containing comments, 26 were found to contain inconsistent communication (5.3%); none reported by pharmacists. An absence of overlap between reported ($n=532$) and unreported ($n=26$) errors of inconsistent communication was not unexpected based on previous literature.¹⁷ In addition, pharmacists do not review refills routinely, and almost a third of the pharmacists reported no errors. Unreported errors discovered through the computerized search and review were used to estimate frequency of the problem. Based on a 5.3% error rate in prescriptions with comments, we estimated the 157 055 prescriptions with comments might contain 8324 prescriptions with inconsistent communication (5.3%). Because these estimated 8324 errors derive from a larger sample of prescriptions with both refills and new prescriptions, we estimate the overall rate of errors of inconsistent information to be 1% (8324 of 830 823).

Table 1 lists the types of inconsistent communication errors in prescriptions reported by pharmacists, frequency of pharmacist contact with providers, and use of free-text information for final prescription fill. The most common inconsistent element across reported prescriptions was drug dosage (44.9%), followed by drug administration schedule (20.5%), duration of medication administration for inpatients (24.4%), medication administration time for inpatients (12.4%), route of administration (3.2%), and quantity of drug requested (1.7%). Pharmacists used the free-text comment in 88.9% of cases to fill the final prescription, the structured template in 9.2% of cases, and in combination in the remainder (1.9%). Pharmacists called providers in 149 cases (28.0%). In the 26 unreported errors, dosage inconsistency was also the most common ($n=10$; data not shown).

Table 2 lists the ordering provider characteristics, setting (inpatient or outpatient), medication classes, and other predictor variables of the 558 total study prescriptions containing inconsistent communication and the 465 controls. The following variables differed significantly between the 2 groups: ordering provider type ($P=.04$) and

specialty ($P<.001$), inpatient vs outpatient setting ($P<.001$), and medication class ($P<.001$). Orders with inconsistent communication were most commonly entered by trainees (59.0%), followed by attending physicians (24.9%), physician assistants (10.2%), and nurse practitioners (5.4%). Most errors (68.3%) occurred in prescriptions for inpatients, and 19.0% ($n=103$) had 2 or more inconsistencies. The following medication classes were most commonly affected by errors: cardiovascular and antihypertensives (15.8%), analgesics (14.7%), antibiotics (10.8%), psychiatric medications (10.4%), and laxatives (7.5%). Only 2 reported errors were discovered after reaching the patient and did not result in harm. Medications needing a complex order (eg, a tapering dose of prednisone) were highly correlated with error. We also compared characteristics of reported and unreported errors in logistic regression analysis. Prescriptions with inconsistencies in schedule and administration route were less likely to be reported by pharmacists than prescriptions without schedule and route inconsistencies (OR, 0.18; 95% CI, 0.06-0.54 for schedule and OR, 0.14; 95% CI, 0.01-0.89 for route; data not shown in Table 2).

Table 3 summarizes the results of the logistic regression model of predictors for inconsistent communication. Inpatient setting (OR, 3.30; 95% CI, 2.18-5.00) and non-primary care specialties such as surgery (OR, 2.45; 95% CI, 1.57-3.82) were more likely to have errors. Certain medication classes were also more likely to have errors, with the highest odds of error occurring for steroids (OR, 7.62; 95% CI, 3.11-18.63) compared with analgesics.

Table 4 lists the potential harms associated with the 558 errors based on the Human Error Consequence Scale²⁰ and the 3 most common drug classes for each category of harm. Even though 29.4% of errors were categorized as inconvenience, 112 errors could have resulted in moderate to severe harm (considerable, very serious, serious permanent damage, or death) (20.1%). Anticoagulants and cardiovascular drugs were the most frequent categories involving moderate to severe harm. **Table 5** summarizes the results of the logistic regression analysis of the 112 errors that could potentially have led to moderate to severe harm.

Table 2. Comparison of Prescriptions With and Without Errors of Inconsistent Communication in Computerized Provider Order Entry^a

Characteristic	Reported and Unreported Errors (n=558)	Controls (No Error) (n=465)	Total (n=1023)	P Value
Ordering provider characteristics				.04
Trainees, interns, residents, fellows	329 (59.0)	238 (51.2)	567 (55.4)	
Attending physician	139 (24.9)	152 (32.7)	291 (28.5)	
Physician assistants	57 (10.2)	43 (9.3)	100 (9.8)	
Nurse practitioners	30 (5.4)	31 (6.7)	61 (6.0)	
Other	3 (0.5)	1 (0.2)	4 (0.4)	
Ordering provider specialty ^b				<.001
Primary care, family, and community medicine	258 (46.4)	295 (63.4)	553 (54.2)	
Surgical specialties ^c	123 (22.1)	51 (11.0)	174 (17.0)	
Mental health	64 (11.5)	52 (11.2)	116 (11.3)	
Spinal cord injury/physical medicine and rehabilitation	46 (8.3)	17 (3.7)	63 (6.2)	
Other medical specialties ^d	23 (4.1)	30 (6.5)	53 (5.2)	
Geriatrics, extended care	26 (4.7)	13 (2.8)	39 (3.8)	
All other, including neurology	16 (2.9)	7 (1.5)	23 (2.3)	
Setting of error				<.001
Inpatient	381 (68.3)	223 (48.0)	604 (59.0)	
Outpatient	167 (29.9)	242 (52.0)	409 (40.0)	
Emergency department	10 (1.8)	0	10 (1.0)	
Medication class				<.001
Cardiovascular and antihypertensive	88 (15.8)	105 (22.6)	193 (18.9)	
Analgesic	82 (14.7)	110 (23.7)	192 (18.8)	
Psychiatric	58 (10.4)	52 (11.2)	110 (10.8)	
Antibiotic	60 (10.8)	15 (3.2)	75 (7.3)	
Laxative	42 (7.5)	18 (3.9)	60 (5.9)	
Nutrient	39 (7.0)	17 (3.7)	56 (5.5)	
Anticoagulant and antiplatelet	39 (7.0)	9 (1.9)	48 (4.7)	
Antidiabetic	12 (2.2)	21 (4.5)	33 (3.2)	
Steroids	19 (3.4)	13 (2.8)	32 (3.1)	
Anticonvulsants	23 (4.1)	2 (0.4)	25 (2.4)	
All other	96 (17.2)	103 (22.2)	199 (19.5)	
Additional predictors				
Complex order	92 (16.5)	0	92 (9.0)	<.001
Not complex order	466 (83.5)	465 (100)	931 (91.0)	
Less frequently prescribed medication	23 (4.1)	11 (2.4)	34 (3.3)	.16
Frequently prescribed medication	535 (95.9)	454 (97.6)	989 (96.7)	
High-alert medication	93 (16.7)	59 (12.7)	152 (14.9)	.08
Not a high-alert medication	465 (83.3)	406 (87.3)	871 (85.1)	

^aUnless otherwise indicated, data are reported as number (percentage) of prescriptions.

^bTwo providers were missing data for provider specialty.

^cSurgical subspecialties includes general surgery, neurosurgery, obstetrics-gynecology, urology, and ophthalmology.

^dOther medical specialties includes endocrinology, hematology, oncology, gastroenterology, cardiology, pulmonology, and dermatology.

Medications ordered by providers in the outpatient setting had higher risk (OR, 2.23; 95% CI, 1.15-4.35) for causing moderate to severe harm than those ordered for inpatients. Medications ordered by providers in specialties other than primary care and surgery had lower risk (OR, 0.30; 95% CI, 0.14-0.63) than those ordered by providers in primary care. Of all medication classes, anticoagulants were associated with the highest risk of causing potentially moderate to severe harm (OR, 61.89; 95% CI, 10.73-356.93). As expected, medications considered high alert (OR, 3.43; 95% CI, 1.62-7.27) had a high potential for causing moderate to severe harm. Of note, 23.1% of unreported errors could have resulted in moderate to severe harm, statistically no different from reported errors ($P=.62$).

COMMENT

We used a combination of 2 methods, pharmacist stimulated self-report and an electronic search followed by

manual review, to describe errors related to inconsistent communication of prescribing information through an advanced CPOE system. Over a 4-month study period, 33 pharmacists reported 532 errors where information entered in the structured template of CPOE did not match the information in the corresponding free-text comment field. We estimate that such errors of inconsistent communication could occur in at least 1% of all CPOE prescriptions and 5.3% of all prescriptions containing free-text comments. Most inconsistencies related to dosage. About 20% of identified errors could have resulted in moderate to severe harm; anticoagulants had the highest risk in a logistic model. Our results suggest that despite attempted standardization of data entry, inconsistent communication poses significant risks to safety achieved by computerized medication order entry.²

Despite the risk of inconsistent communication and the inability to run system cross-checks against the uncoded free-text data, several benefits exist. In a previous

Table 3. Logistic Regression Model of Predictors for Errors of Inconsistent Communication in Computerized Provider Order Entry

Characteristic	Odds Ratio (95% Confidence Interval)	P Value
Setting of error		
Inpatient vs outpatient	3.30 (2.18-5.00)	<.001
Ordering provider specialty		
Surgical vs primary care	2.45 (1.57-3.82)	<.001
Spinal cord injury vs primary care	4.01 (1.82-8.82)	<.001
Geriatrics vs primary care	1.62 (0.62-4.21)	.32
Other medicine vs primary care	0.82 (0.42-1.63)	.58
Psychiatry vs primary care	1.22 (0.70-2.11)	.48
All other vs primary care	2.48 (0.97-6.34)	.06
Ordering provider characteristics		
Nurse practitioner vs attending	0.66 (0.25-1.78)	.41
Physician assistant vs attending	1.33 (0.54-3.29)	.54
Trainee vs attending	0.65 (0.38-1.10)	.11
Medication class		
All other meds vs analgesic	4.50 (2.87-7.03)	<.001
Cardiovascular vs analgesic	2.17 (1.31-3.59)	.002
Laxatives vs analgesic	4.92 (2.32-10.43)	<.001
Nutrients vs analgesic	6.03 (2.82-12.90)	<.001
Psychiatric vs analgesic	2.98 (1.64-5.40)	.001
Steroids vs analgesic	7.62 (3.11-18.63)	<.001
Antidiabetic vs analgesic	0.94 (0.35-2.52)	.90
Predictors		
High alert vs not high alert	1.95 (1.24-3.07)	.003

study, 92% of users reported that CPOE was inflexible⁹; the free-text window offers a valuable option to communicate clarifications or nonstandard information. In fact, in over 90% of cases the pharmacists used the free-text information either by itself or combined it with information from the structured template, underscoring the importance of this window. Given other advantages of using unconstrained, narrative information in computerized information systems,^{5,14} we believe the free-text window should be maintained in CPOE systems but with improvements to avoid inconsistencies.

We obtained a comparable estimate of error rate (ie, 1%) using both reporting and electronic search, adding strength to our findings. Additional study strengths include a large variety of medications, a large number of providers (>500), and an advanced CPOE system fairly representative of other systems. All CPOE systems have some method of entering free text. Chused et al²¹ recently reported communication failures resulting from free-text comments entered in response to alert overrides, suggesting that commercial CPOE systems may not also protect against the problem. To our knowledge, this is also the first study reporting errors of communication due to free-text comments in CPOE systems.

We have drawn several preliminary conclusions about the origin of inconsistent communication and propose some preliminary interventions. First, providers often selected an automated dosage default rather than typing

Table 4. Outcome Categories for Harm From Errors of Inconsistent Communication in Computerized Provider Order Entry

Numbered Outcome Categories for Harm ^a	Across All Error Categories, No. (%)	Top 3 Most Common Drug Classes (%) ^b
1—No Error No error in the performer's task performance could result in harm to a human	0	Not applicable
2—Inconvenience The most serious likely error in the performer's task performance would result in physical or mental inconvenience	164 (29.4)	Analgesic (25.0) Laxative, hyperosmotic (15.2) Antibiotic (11.6)
3—Very minor harm/little or no remediation The most serious likely error in the performer's task performance would result in minor physical or mental harm, requiring little or no remediation	159 (28.5)	Analgesic (19.5) Psychiatric (16.4) Antibiotic (12.6)
4—Minor harm/remediation or treatment The most serious likely error in the performer's task performance would result in minor physical or mental harm and would require remediation or treatment	123 (22.0)	Cardiovascular (22.0) Psychiatric (14.6) Anticonvulsant (8.9) Steroid (8.9)
5—Considerable harm/remediation or treatment The most serious likely error in the performer's task performance would result in considerable physical or mental harm and would require remediation or treatment	70 (12.5)	Cardiovascular (34.3) Antibiotic (15.7) Anticoagulant (15.7)
6—Very serious harm/danger of permanent damage The most serious likely error in the performer's task performance would result in very serious physical or mental harm or harm that would put the affected person in danger of minor permanent damage	26 (4.7)	Anticoagulant (46.2) Cardiovascular (26.9) Nutrient (7.7)
7—Serious permanent damage The most serious likely error in the performer's task performance would result in serious permanent damage beyond the help of remediation or treatment	15 (2.7)	Anticoagulant (53.3) Cardiovascular (13.3) Immune suppressant (13.3)
8—Immediate and inevitable death The most serious likely error in the performer's task performance would result in immediate and inevitable death	1 (0.2)	Exchange resin ^c (100.0)

^aTwo investigators (a physician and a pharmacist) assigned harm categories by consensus using the Human Error Consequence Scale.²⁰

^bOf all errors in a given harm value, this is the percentage of errors that were in the most common drug class. For example, of all errors of harm value 2, the most common drug class was analgesics, which accounted for 25.0% of all drug classes with errors in that harm value.

^cThere was only 1 drug class in this harm level.

Table 5. Logistic Regression Analysis of Predictors for Moderate to Severe Harm^a From Errors of Inconsistent Communication in CPOE

Characteristic	Odds Ratio (95% Confidence Interval) ^b	P Value
Setting of error		
Outpatient vs inpatient	2.23 (1.15-4.35)	.02
Ordering provider specialty		
Surgical vs primary care	1.33 (0.62-2.89)	.47
Other vs primary care	0.30 (0.14-0.63)	.002
Ordering provider characteristics		
Nurse practitioner vs attending	0.65 (0.16-2.58)	.54
Physician assistant vs attending	0.38 (0.14-1.04)	.06
Trainee vs attending	0.84 (0.40-1.78)	.65
Medication class		
All other medications and/or antidiabetic vs analgesic	7.99 (1.48-42.99)	.02
Antibiotic vs analgesic	8.58 (1.64-44.83)	.01
Anticoagulant vs analgesic	61.89 (10.73-356.93)	<.001
Anticonvulsant vs analgesic	9.70 (1.33-71.01)	.03
Cardiovascular vs analgesic	17.98 (3.85-84.01)	.001
Laxatives vs analgesic	1.92 (0.23-16.36)	.55
Nutrients vs analgesic	7.05 (1.17-42.61)	.03
Psychiatric vs analgesic	1.57 (0.18-13.91)	.69
Steroids vs analgesic	3.92 (0.44-34.55)	.29
Predictors		
High alert vs not high alert	3.43 (1.62-7.27)	.001
Unusual and/or low frequency vs not unusual and/or low frequency	1.50 (0.40-5.57)	.55

Abbreviation: CPOE, computerized provider order entry.

^aModerate to severe harm was defined as harm categories 5 through 8 of the Human Error Consequence Scale²⁰ (see Table 4).

^bAlthough the confidence intervals are large, we did not combine the medication classes to obtain more precise estimates because we wanted to assess the odds of harm for each separate medication.

the desired dosage. Although defaults can be helpful, they may not be comprehensive and may be based on inventory rather than clinical guidelines. We found some defaults to be needlessly restrictive (eg, administration time). Although default settings are designed to save time and increase efficiency, it appeared that providers did not realize many could be changed. While default options may improve care in some settings,²² our results suggest a need for more careful consideration before their use.

Second, comments were transferred to the new prescription when modifying an existing prescription. This may not be appropriate, and we suggest that system developers force users to actively request such transfers.

Third, insufficient knowledge of the ordering mechanism appears to be a common problem, and simple training on the use of complex orders for certain prescriptions could reduce errors. For instance, providers would often use the free-text window to write complex prescriptions that were frequently associated with error (eg, prednisone taper). Certain specialties had higher odds for error perhaps because they wrote relatively fewer prescriptions or were less familiar with CPOE.

Finally, many of the errors and issues suggest that standardization through CPOE was not adequately integrated with the workflow, needs, and preferences of the providers.^{23,24} For instance, we found errors that could be prevented by minor modifications in the CPOE template regarding administration time or duration and/or stop time for a medication.

Our study adds to the growing body of knowledge that computerized information systems may introduce new types of errors, including those involving communica-

tion processes.^{5,25} Future studies should address the usability of the CPOE interface to identify breakdown points and maximize the effectiveness, efficiency, and satisfaction of electronic communication.^{26,27} Using a multifaceted interdisciplinary approach to the problem would generate the best solutions.^{28,29} Interventions aimed at reducing communication errors at the human-CPOE interface³⁰ will need grounding in principles of human-computer interaction.

Even though most errors of inconsistent communication would have caused inconvenience or minor harm, the potential for more severe harm is significant, given the large volume of prescriptions written. Certain commonly prescribed medications such as anticoagulants posed a particularly high risk for moderate to severe harm. Pharmacists continue to play a prominent role in achieving medication safety in advanced CPOE systems.³¹

We note several limitations of our study. It was conducted at a single site where all providers used the same CPOE system, and although it involved a large number of patients and providers, including trainees, generalizability may be limited. Because underreporting is a well-recognized phenomenon in similar studies, our findings may underestimate the problems caused by inconsistencies in the orders; the 12 pharmacists who chose not to participate cited time as a factor. Other studies have also found significant differences among pharmacists in error reporting.³² Only slightly more than two-thirds of eligible pharmacists participated in the study, and hence there is almost certainly selection bias. Furthermore, while it is likely that similar communication breakdowns occur in other Veterans Affairs facilities using the same CPOE system, we ac-

knowledge that the true prevalence across Veterans Affairs institutions is unknown. Despite these limitations, we believe that this project highlights an important issue and serves as a model for others seeking to enhance safety and usability of advanced CPOE systems.

In conclusion, in spite of attempted standardization of data entry, inconsistent communication poses a significant risk to safety achieved by CPOE. We found that errors related to inconsistent information in a state-of-the-art CPOE system occurred in at least 1% of all prescriptions, and this rate increased to at least 5% in a sample of prescriptions with associated free-text comments. Although most errors we studied did not reach the patient because of pharmacist intervention, they pose a significant potential risk to patients. The potential for moderate to severe harm is likely more significant given the expected increase in the volume of prescriptions written through future CPOE systems. Improving the usability of the CPOE interface and integrating it with workflow may reduce this risk. Future studies should identify breakdown points and maximize the effectiveness, efficiency, and satisfaction of electronic communication through CPOE.²⁶

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