How Many Medication Orders are Entered through Free-text in EHRs? - A Study on Hypoglycemic Agents

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Abstract

Computerized Provider Order Entry (CPOE) can reduce medication errors; however, its benefits are only achieved when data are entered in a structured format and entries are properly coded. This paper aims to explore the incidence of free-text medication order entries involving hypoglycemic agents in an ambulatory electronic health record (EHR) system with CPOE. Our results showed that free-text order entry continues to be frequent. During 2010, 9.3% of hypoglycemic agents were entered as free-text for 2,091 patients. 17.4% of the entries contained misspellings. The highest proportion of free-text entries were found in urgent care clinics (49.4%) and among registered nurses (31.5%). Additionally, 92 drug-drug interaction alerts were not triggered due to free-text entries. Only 25.9% of the patients had diabetes recorded in their problem list. Solutions will require policy to enforce structured entry, ongoing improvement in user-interface design, improved training for users, and strategies for maintaining a complete medication list.

1. Introduction

Medication errors are among the most common medical errors, affecting nearly 1.5 million people and contributing to over 7,000 deaths annually.[1] Costs associated with these errors are estimated to be in the billions,[2] The introduction of Computerized Provider Order Entry (CPOE) in the 1970s was one of the first steps towards reducing common medical errors by targeting errors associated with handwritten orders and providing a link between structured electronic data entry and quality of care.[1, 3] Following CPOE, medication reconciliation was introduced, which encourages health providers to maintain a complete and accurate medication list within electronic health records (EHRs).

Studies of CPOE implementations provide compelling evidence suggesting that medication errors can be reduced by up to 80%, and errors associated with morbidity or death by 55%.[4-6] Studies have also suggested computerized medication reconciliation can decrease medication discrepancies.[7] The realization of these benefits, however, is only achieved when data are entered in a structured format and needed details (e.g., medication names) are properly coded. Thus far, few studies have focused on free-text orders entered within a CPOE or EHR system. This paper aims to explore the incidence of free-text medication order entries involving hypoglycemic agents in an ambulatory EHR system with CPOE. We consider the possible reasons for free-text medication orders and the challenges it presents to our goal of improving patient care.

2. Background

It is widely recognized that in order to use health information technology (HIT) to improve healthcare quality, safety and efficiency, the technology should be used in meaningful ways. Meaningful Use Stage 1 measures require "more than 80% of all unique patients seen by the eligible professional or admitted to an eligible hospital ... have at least one medication order (or indication that the patient is not currently prescribed any medication) recorded as structured data." Further, "more than 40% of all permissible prescriptions written by the eligible professional" should be "transmitted electronically using certified EHR technology."[8]

Enhancements to CPOE and e-prescribing systems have made it possible to reduce medical errors by cross-checking allergies, duplicate medication orders, and drug-drug interactions, while assisting the prescriber with standard dosing and frequency selection. Computerized medication reconciliation provides the user with the ability to electronically compare two or more medication lists. While useful, these systems require the data to be entered in a structured and coded format, which makes it possible for computers to use the information for clinical decision support (CDS). Entering medications orders using free-text ("uncoded") disables the automatic triggering of computerized CDS, thereby allowing opportunities for error. To date, little research has been done in studying the incidence of free-text medication orders in CPOE or EHRs. Singh et al[9] compared the inconsistencies between structured orders and the accompanying free-text fields to identify prescription errors. Other studies have found that users sometimes work around CDS "hard stops" by using free-text orders.[10] Despite the plentiful benefits awarded by HIT, its adoption by hospitals and doctors is slower and more problematic than anticipated.[8, 11] Physician resistance is one of the top barriers for the implementation of CPOE. Reasons are multifold and complex, including human-computer interaction flaws, interference with clinical workflow, CDS alert fatigue, inadequate system training, system errors, etc.[8, 12]

In this study, we aim to investigate the incidence of free-text medication order entries in an outpatient setting over a one year time period. We consider the characteristics of patients and their prescribers, as well as possible underlying reasons for free-text entries. As a first step, we decided to investigate high alert medications, namely insulin, oral hypoglycemic agents, and injectable non-insulin hypolycemic agents used to treat diabetes. According to the CDC, 8.3% of the US population was diagnosed with diabetes in 2010.[13] Diabetes is the seventh most common cause of death and remains the leading cause of kidney failure, non-traumatic lower-extremity amputations, and blindness among adults. Many patients with diabetes require taking hypoglycemic agents, most notably exogenous insulin, to prevent hyperglycemia and life-threatening ketoacidosis. Appropriate administration of these medications can prevent morbidity and reduce mortality associated with diabetes. Insulin preparations or hypoglycemic agents are listed as the most notable high alert medications by the *Institute for Safe Medication Practices*.[14] High alert medications are classified as such because they exhibit the highest potential for causing adverse drug events, overdose, and death when used improperly. A recent study by Budnitz *et al* showed that nearly two thirds of geriatric hospitalizations are due to unintentional overdose, of which insulin is ranked second (13.9%) and oral hypoglycemic agents are ranked fourth (10.7%)[15]. Gurwitz et al showed that hypoglycemic agents are responsible for 6.8% of total adverse drug events (ADEs) and are associated with the most preventable ADEs.[16] A study conducted by Bates *et al* demonstrated that the implementation of CPOE resulted in a 50% decrease in medication error rates of diabetic drugs.[5]

3. Methods

3.1. Setting and data collection

Partners Healthcare System (PHS) is an integrated health care system in the Boston area, founded in 1994 by Brigham and Women's Hospital and Massachusetts General Hospital. PHS also includes community and specialty hospitals, community health centers, and other health-related entities. The Longitudinal Medical Record (LMR) is the ambulatory EHR system used across PHS by over 4,000 clinicians. The LMR includes a CPOE module with CDS. Structured medication order entry is supported by an enterprise Master Drug Dictionary (MDD), which gives the prescriber the opportunity to check the medication name, dose, frequency, contraindications, drug interactions, drug allergies, and duplicate therapy by both specific drug and drug class. Free-text orders are permitted within the LMR to provide flexibility for the prescriber when a given medication is not yet available in the MDD.

We retrieved free-text medication entries from the patient's medication list in the LMR over a one-year time period in 2010. Data were obtained through the PHS Quality Data Management Warehouse. Both prescription and non-prescriptions (e.g., over-the-counter medications) were included. We manually reviewed all free-text entries and identified patients who had free-text hypoglycemic medication order entries, including insulin, oral hypoglycemic drugs, and injectable non-insulin hypoglycemic agents. For the patients with these entries, we retrieved their demographic information (e.g., age, sex, and race), other coded hypoglycemic medication order entries, and clinical diagnoses from the LMR problem list. Patients who had a diagnosis of diabetes (including type 1 and 2 diabetes mellitus, and also gestational diabetes mellitus) were identified based on a set of ICD-9-CM codes, SNOMED codes, or PHS local problem list codes, as well as a free-text keyword search since problems/diagnoses can also be entered as free-text. For the clinicians who entered free-text hypoglycemic drug entries, their demographic data and clinic information were also retrieved. This study was approved by the PHS Human Research Committee.

3.2. Data analysis

We analyzed the characteristics of free-text hypoglycemic entries, the possibility of having these entries encoded with a medication present in the MDD, and the overall percentage of free-text entries.

For patients who had free-text hypoglycemic drugs on their medication lists, we calculated the number of free-text and coded entries per patient. We also examined their demographic characteristics and the number of patients who were diagnosed with diabetes. For clinicians who entered free-text hypoglycemic medications, we examined their role (e.g., physician, nurse practitioner, etc.). We analyzed demographic characteristics of physicians, since other providers' demographic information was not available in our study database.

We calculated the number of free-text entries, the number of coded entries, and the percentage of overall free-text entries by provider role and clinic type. The number of misspelled free-text entries was calculated and also analyzed at the provider role and clinic type level. We also examined the possible drug-drug interaction (DDI) alerts as well as alerts for therapy duplication that were missed due to free-text order entry.

Patient and provider data were managed in a Microsoft SQL Server (version 8.0) database and data analysis was performed with SAS software version 9.2 (SAS Institute Inc., Cary, North Carolina, U.S.).

4. Results

4.1. Free-text hypoglycemic medication order entries

Overall, 2,412 hypoglycemic drugs were entered using free-text for 2,091 patients in the LMR during 2010, accounting for 9.3% of the overall 26,001 hypoglycemic medication order entries for these same patients. As shown in Table 1, 68.5% of these free-text hypoglycemic drugs were insulins, 16.4% were insulin response enhancers, 12.9% were oral hypoglycemic agents, and 2.2% were injectable non-insulin hypoglycemic agents. In addition to drug names, we also examined free-text details related to dose, route, frequency, duration, and quantity dispensed. More than 40% of dose, frequency, and dispense quantity details, and approximately 80% of duration information were missing. Route information (e.g., subcutaneously or oral) was filled most of the time.

Table 1. Free-text Hypoglycemic Drug Group (n=2412)

	N (%)
Hypoglycemic Drug Group	
Insulin (human insulin and insulin analog)	1652 (68.5)
Insulin response enhancer (e.g., Metformin, Glucophage, Actocs)	396 (16.4)
Oral hypoglycemic (e.g. Glipizide, Glimepiride, Actoplus)	312 (12.9)
Injectable non-insulin hypoglycemic (e.g., Symlin, Byetta, Victoza)	52 (2.2)
Missing Values in Other Fields in Medication List	
Dose	1087 (45.1)
Route	21(0.9)
Frequency	1036 (43.0)
Duration	1900 (78.8)
Dispense Quantity	1187 (49.2)

4.2. Can these entries be coded?

We found that 75.2% of these free-text entries have an exact name match in the PHS medication dictionary (MDD). That is, if providers searched these free-text drug names in the order entry user interface, and if the names were correctly spelled, they could find an exact name match and these orders could be coded automatically. The remaining 24.8% of the free-text entries (e.g., human insulins and actoplus) could be coded if specific formulation information was also provided. In this case, when a user enters "insulin" or "actoplus", the system requires the user to also provide formulation information such as "Insulin lispro kwikpen 50/50" or "actoplus MET XR".

4.3. Patient characteristics

The characteristics of the patients whose hypoglycemic medications were entered as free-text are summarized in Table 2. The average age of the patients was 58.5 (range 4-99) years old with 42.5% of patients being over 65 years old. Race was 65.3% white and sex was 49.7% female. Only 25.9% of these patients had diabetes recorded in their problem list.

On average, each patient had 1.2 free-text medications recorded. 87% had one free-text entry and 13% had two or more free-text entries. 33.5% of patients only had free-texted hypoglycemic drug entries on their medication lists in the LMR. Of the remaining 66.5% of patients who also had coded hypoglycemic medication entries, 29.7% of patients had one coded entry, 19.6% had two and 17.2% had over three.

Table 2. Characteristics of Patients Who Had Free-text Hypoglycemic Drug Entries on Their Medication Lists (n=2091)

Patient Characteristic	No (%) of Patients
Age, mean (range), y	58.5 (4-99)
Age group	
0-18	87 (4.2)
19-40	270 (12.9)
41-64	846 (40.5)
≥65	888 (42.5)
Sex	
Female	1040 (49.7)
Male	1051 (50.3)
Race or ethnic group	
Asian	46 (2.2)
Black	105 (5.0)
Hispanic	94 (4.5)
White	1366 (65.3)
Unknown or others	439 (23.0)
Diagnosed with diabetes	
Yes	542 (25.9)
No	1549 (74.1)
No. of free-text hypoglycemic drugs	
Mean (range)	1.2 (1-5)
1	1820 (87.0)
2	232 (11.1)
3	30 (1.4)
4	7 (0.3)
5	2 (0.1)
No. of coded hypoglycemic drugs	
Mean (range)	1.3 (0-8)
0	700 (33.5)
1	620 (29.7)
2	410 (19.6)
3	193 (9.2)
4	105 (5.0)
5	63 (3.0)

4.4. Provider characteristics

There were 722 healthcare providers identified as ordering these free-text hypoglycemic agents. Providers' characteristics are shown in Table 3. Among these, 61.1% were physicians, 8.0% nurse practitioners (NP), 6.7% registered nurses (RN), 1.5% physician assistants (PA), 1.5% pharmacists, and 21.2% were unspecified. The unspecified providers were most likely non-physicians. Only physicians' demographic data was available in our study database. The average age of the physicians was 49.6 (range 28-82) years old. 27.9% were under 40 years old, 26.3% were between 41-50, 22.9% were between 51-60, and 21.8% were over 60. Of the physicians who entered free-text medications, 56.2% were male.

4.5. Free-text order entries by provider role and clinic type

Table 4 shows the number of free-text and coded hypoglycemic medication order entries as well as the proportion of free-text entries by provider role and clinic type. For the 2,412 free-text order entries, 58.7% were entered by physicians, 12.4% by NPs, 7.8% by RNs, and 1.1% by PAs and pharmacists. RNs demonstrated the highest proportion of free-text entries at 31.5% followed by PAs at 12.5%, pharmacists at 11.8%, NPs at 10% and physicians at 7.3%.

Free-text entries occurred across 186 different clinics. We categorized these clinics into a set of types, such as general/internal medicine and primary care, ophthalmology, and endocrine/diabetes centers, as shown in Table 4. Hypoglycemic medications were entered mostly in general/internal medicine and primary care clinics, followed by ophthalmology clinics, and then by endocrine/diabetes centers. However, compared to general/internal medicine and primary care, where the free-text rate was 4.6%, specialty clinics are more likely to use free-text entries. About half of the hypoglycemic medications were entered in free-text in urgent care clinics, 27.3% in ophthalmology, 17.0% in oncology, 14.9% in pediatric clinics, and 8.1% in endocrine and diabetes centers.

Table 3. Characteristics of Providers Who Entered Free-text Hypoglycemic Drugs in Medication Order Entry

Provider Role	**No (%) of 722 Providers**
Physicians	441 (61.1)
Physician Assistant (PA)	11 (1.5)
Nurse Practitioner (NP)	58 (8.0)
Registered Nurse (RN)	48 (6.7)
Pharmacist	11 (1.5)
Unspecified	153 (21.2)
Physician Demographics	**No (%) of 441 Physicians**
Age, mean (range), y	49.6 (28-82)
Age group	
28-40	123 (27.9)
41-50	116 (26.3)
51-60	101 (22.9)
> 60	96 (21.8)
Unspecified	5 (1.1)
Sex	
Female	188 (42.6)
Male	248 (56.2)
Unspecified	5 (1.1)

Table 4. Frequency of Free-text and Coded Hypoglycemic Drug Entries by Provider Role and Clinic Type (n=2412)

	No. (%) of free-text entries a	**No. (%) of coded entries b**	**Proportion of free-text over all entries by type; % a/(a+b)*100**
Provider role			
Physician	1416 (58.7)	18096 (76.7)	7.3
Physician Assistant	12 (0.5)	84 (0.4)	12.5
Nurse Practitioner	299 (12.4)	2678 (11.4)	10.0
Registered Nurse	189 (7.8)	411(1.7)	31.5
Pharmacist	14 (0.6)	105 (0.4)	11.8
Unspecified	482 (20.0)	2215(9.4)	17.9
Clinic type			
General/Internal medicine and primary care	651 (27.0)	13422 (56.9)	4.6
Ophthalmology	585 (24.3)	1561 (6.6)	27.3
Endocrine/diabetes center	347 (14.4)	3922 (16.6)	8.1
Urgent care	133 (5.5)	136 (0.6)	49.4
Pediatrics	122 (5.1)	695 (2.9)	14.9
Oncology	100 (4.1)	487 (2.1)	17.0
Women's care	61 (2.5)	464 (2.0)	11.6
Cardiology	35 (1.5)	336 (1.4)	9.4
Others	378 (16.7)	2566 (10.8)	12.8
Total	2412	23589	9.3

4.6. Misspellings

Overall, 17.4% of free-text hypoglycemic medication order entries contained misspellings. RNs had the highest misspelling rate at 22.8% and pharmacists had the lowest rate at 7.1%. The misspelling rates of physicians, NPs and PAs were 13.5, 12.4% and 16.7%, respectively.

Not surprisingly, compared to other clinics, the misspelling rate of hypoglycemic medications in endocrine and diabetes centers was low (2.9%). Misspelling rate in pediatric clinic was also relatively low (4.9%). In other clinics, misspellings were common. For example, in oncology and ophthalmology clinics, 31% and 25% of the free-text entries contained misspellings, respectively. Commonly misspelled terms included "Glimepiride", "Glipizide", "Glyburide", "Humalog", "Humulin", "Novolog", and "Novolin".

Table 5. Frequency of Misspelled Free-text Hypoglycemic Drug Entries by Provider and Clinic Type (n=420)

	No. (%) of Misspellings a	No. (%) of free-text entries b	Proportions of Misspellings by role/type;% a/b*100
Provider role			
Physician	191 (45.5)	1416 (58.7)	13.5
Physician Assistant	2 (0.5)	12 (0.5)	16.7
Nurse Practitioner	37 (8.8)	299 (12.4)	12.4
Registered Nurse	43 (10.2)	189 (7.8)	22.8
Pharmacist	1 (0.2)	14 (0.6)	7.1
Unspecified	146 (34.8)	482 (20.0)	30.3
Clinic type			
General/Internal medicine & Primary care	113 (26.9)	651 (27.0)	17.4
Ophthalmology	147 (35.0)	585 (24.3)	25.1
Endocrine/diabetes center	10 (2.4)	347 (14.4)	2.9
Urgent care	22 (5.2)	133 (5.5)	16.5
Pediatrics	6 (1.4)	122 (5.1)	4.9
Oncology	31 (7.4)	100 (4.1)	31.0
Women's care	13 (3.1)	61 (2.5)	21.3
Cardiology	4 (1.0)	35 (1.5)	11.4
Others	74 (17.6)	378 (16.7)	19.6
Total	420	2412	17.4

4.7. Clinical decision support

PHS currently has 114 drug-drug interaction (DDI) rules related to hypoglycemic agents. These alerts are tiered to three levels: 2 alerts are "hard-stop", 7 are interruptive alerts for which users need to provide an override reason, and 105 are informational alerts. We ran these DDI rules against the patients' overall medication lists, and found that 92 informational DDI alerts were not triggered due to free-text entries, affecting 84 different patients.

4.8. Duplications

We found that 196 patients who had a free-text hypoglycemic order entry also had the same exact drug entered as a structured and coded order during 2010. Entries were considered identical if they contained the same active ingredient, as seen with brand and generic medications (e.g., "lantus" vs "insulin glargine"). Exclusion criteria took into account difference in release (e.g., "Metformin" and "Metformin ER") and differences in formulation (e.g., "Novolin" and "Novolin 70/30"). In these 196 patients, less than 10% had identical drug entries active in their medication list at the same time. For the remaining cases, providers were not consistent in their use of coded or free-text entries and tended to switch between the two. Possible reasons may be attributable to entry by different providers, regimen change, medication refills, or misspelling corrections.

5. Discussion

In this study, we examined free-text hypoglycemic medication order entries in an ambulatory EHR. Our study showed these entries continue to be prevalent despite innovations in CPOE/e-prescribing, CDS, medication reconciliation, and other health information technology. Nearly 10% of hypoglycemic medications were entered as free-text. Insulin was implicated in approximately two thirds of the cases, and oral hypoglycemic and non-insulin preparations in the remaining third. Approximately 75% of the free-text order entries had exact matches in our drug dictionary, thereby enabling them to be initially entered as coded entries. Zheng et al found that 63% of medication prescriptions could have been coded, which is consistent with what is reported in this paper.[17] The highest proportion of free-text order entries were found in urgent care clinics and among registered nurses. These results are unsettling in light of Budnitz et al's study citing insulin and oral hypoglycemic agents as one of the top contributors of emergency department visits and hospitalizations.[15]

While free-text offers expediency, the accuracy of free-text entries is questionable. Clinicians most likely perceive that they are entering a complete order, but Nanji et al[18] found that about one in ten computer-generated prescriptions include at least one error, of which a third has the potential for harm. Error types can include dose, duration, frequency, route, formulation, etc. We found that a significant portion of free-text order entries were missing one or more of these required details for order completion. In addition, 17.4% of free-text medication order entries were misspellings. These findings draw attention to the potential for error when using free-text medication orders despite their convenience.

It is worth noting that there is an LMR code for patients who have no prescribed medications. If and when a drug is prescribed for this patient, the system will automatically remove the "non-medication" code. However, we found that for many cases, providers typed in free-text (e.g., none, no meds) and many of these entries remained on the patient's medication list even after medications had been entered. This raises another concern since meaningful use criteria require the "indication that the patient is not currently prescribed any medication" be recorded as structured data.

CPOE/e-prescribing systems allow a physician, nurse practitioner, or physician assistant to electronically transmit accurate, error-free, and understandable prescriptions directly from the point of care to the pharmacy. These systems meant to reduce the risks associated with traditional prescription script writing. Free-text, misspelled order entries could serve as a bottleneck for achieving data transmission and integration, clinical decision support, and other functions of the CPOE/e-prescribing systems.

5.1. Clinical decision support and potential outcomes

With regard to decision support, CDS is not triggered when a medication order is entered as free-text. Consequently, all current and future CDS alerts, including, drug-disease, drug-drug interaction (DDI), and duplicate therapy checking, will be continuously bypassed. For example, the hypoglycemic drug Metformin carries a risk of lactic acidosis, a potentially life-threatening condition that is increased in patients with renal or hepatic insufficiency.[19] The FDA mandates Risk Evaluation and Mitigation Strategies (REMS) for Metformin and its combination products (e.g., Janumet and ActoMet). These include consideration of relevant laboratory results prior to initiating treatment (e.g., blood glucose, serum creatinine, and liver function tests). Within PHS, these "relevant labs" can be linked to coded medication orders to inform the physician on the appropriate dosage of a particular drug, or its contraindications. These links are not possible for free-text entries. Regarding DDI checking, there are currently 114 interactions involving hypoglycemic medications within the PHS DDI knowledge base, ranging from level 1 hard stops, level 2 interruptive, to level 3 informational alerts. For example, medications like Metformin, which was included in 385 free-text entries, currently triggers two hard stop alerts, as well as some level 2 interruptive drug interaction alerts. These CDS aspects are critical to patient safety and if unintentionally bypassed due to free-text medication order entries may result in potential harm to the patient.

Another foreseeable outcome of free-text medication order entry is the potential for drug duplication and drug overdose. We found approximately 9.4% of patients had identical free-text and coded hypoglycemic entries listed. Duplicate therapy alerts typically check both drug-class (e.g., Glipizide versus Sulfonylureas) and drug-drug duplications (e.g., Metformin versus Metformin ER). In addition, a free-text drug may be expressed as either a brand name or a generic. Hence, it is possible that free-text order entries could result in a patient receiving both a generic and a brand name prescription (e.g., Insulin regular and Novolin 70/30) and if the clinician did not provide clear instructions, the patient may be taking both. The Institute for Safe Medication Practice (ISMP) has cited medication errors where drugs available under multiple names are not always recognized as the same medication.[20] A Food Drug Administration (FDA) search of the ingredient metformin yielded 11 pages worth of products.[21] The role of a structured medication order entry cannot be overstated in the context of this type of error.

Our study also indicates that maintaining a complete, accurate and structured medication and problem list with free-text order entries is a challenging task. For example, The PAML (Partners Admission Medication List) in PHS' EHR systems is designed to compare inpatient and outpatient medications based on therapeutic class. This classification tool can only be invoked for structured medication entries. Free-text medications, while included, are sorted to the bottom making the PAML a less effective tool for clinicians. Our results also show that 74.1% of patients who have free-text hypoglycemic medication orders listed in the LMR did not have a diagnosis of diabetes in their problem list. These patients depend on human foresight for diabetic control instead of an automated alert system. The patients with at least one coded hypoglycemic medication will benefit from the drug-diagnosis function that is being introduced into the LMR.[22] This will prompt the user to add a diabetic diagnosis whenever a coded hypoglycemic agent or insulin is entered and no prior diagnosis exists. However, patients with EHR's containing only free-texted hypoglycemic medication orders will continue to bypass the cues of this problem list enhancement.

5.2. Possible reasons and solutions

The adoption of CPOE has been slowed by resistance to costs and training time involved, changes in physician's workflow and practice patterns, concern with product/vendor immaturity (e.g., inefficient user-interface design) and system interoperability and compliance with future national standards.[23] Studies have also shown that CPOE presents several possible dangers by introducing new types of errors.[8] Despite recent incentive programs launched by the government and innovations in HIT, adoption and meaningful use of CPOE still faces many challenges. There are many conceivable reasons for the entry of free-text medication orders. In the following, we explore possible reasons and related issues, and then suggest potential solutions.

5.2.1. Workflow and system design

Highest rates of free-text entries were noted in urgent care. In this setting, where treating patients quickly and efficiently is expected, it is possible clinicians may enter a free-text order because they do not have time to search for a specific drug, particularly if there is a long list to sort through, or if the drug is not in their "favorites list". For providers (e.g., in ophthalmology and oncology clinics) unaccustomed to insulin and hypoglycemic agents, finding the exact formulation may be difficult (e.g., Novolin vs. Novolin 70/30), which may lead them to use free-text order entries. However, it is alarming that providers in an endocrine/diabetes center, who prescribe hypoglycemic drugs on a regular basis, also tended to use free-text. This suggests that many other factors may play a role. Inefficient user interface may serve as a key underlying reason for the use of free-text, particularly if they involve navigating through multiple screens. Another reason may be search functions. Currently, the medication entry field in the LMR provides the prescriber with a coded version of their searched term. However, the search function is limited to only detecting exactly spelled MDD medication names.

System improvement should focus on designing an efficient user-interface to address workflow issues. To date, most user-interfaces in CPOE systems and EMRs fall short of users expectations with clinicians citing multiple areas for improvement. Ideally the user interface should closely reflect the practice patterns of the clinician. Consideration should be given to limiting the number of screens and mouse clicks to enter medications in the system. In addition, entering a coded medication should be as easy as entering a free-text medications. Allowing the user choose from a pick-list or favorites list (where free-text entries should be monitored and cleaned up regularly), or have a selection of drugs to choose from as they type (auto-fill) will facilitate coded order entry. Additionally, as voice recognition technology continues to improve it may offer a more efficient way of searching and entering coded medication orders with the added capability of verbal confirmation of a medication order. Furthermore, advancing search functions may help reduce free-text these entries. For example, if the clinician enters a free-text order for metformin, triggering clinical decision support and employing either natural language processing or machine learning techniques could provide a list of suggestions. This strategy will provide the clinician an opportunity to select a coded medication in place of the free-text order without having to leave the order entry screen.

5.2.2. Issues related to medication reconciliation

Currently at many practices, providers are encouraged to conduct medication reconciliation. Meaningful Use Stage 2 proposes the provider maintain a complete and reconciled medication list for patients, "including name, dosage, frequency, and route by comparing the medical record to an external list of medications obtained from a patient, hospital or other provider".[24] Based on our interview with some providers in ophthalmology clinics where the free-text rate was 27.3%, we found that these clinics cater to a substantial population of patients with providers outside the PHS network. Providers at ophthalmology clinics were usually not the prescribers of hypoglycemic agents. They entered these drugs prescribed elsewhere into patients' medication list to maintain a complete, up-to-date list. In addition, incomplete and inaccurate information provided by the patients added more complexity and uncertainty as to exact product or formulation. For example, a patient may state they "take insulin" but are unable to provide the level of detail to allow the correct formulation to be selected from the coded list. A seemingly simple solution may be using prescription barcodes, included on most if not all prescriptions, to scan their medications into the EHR much like inpatient barcode medication administration. If however, the patient does not have their medications with them; free-text entry may be the only viable option, although discouraged by current policy. Other specialty clinics (e.g., oncology) may have the same situation. The challenges of maintaining a reconciled medication list indicate the need for system interoperability and data exchange, which allow an EHR to receive medication information from other sources such as pharmacy claims data.

5.2.3. CDS fatigue

Frequent alerts and warnings can interrupt workflow, causing these messages to be ignored or overridden due to alert fatigue. If the clinician finds the drug but the coded medication order results in multiple known alerts, the clinician may become frustrated with these alerts and choose to enter free-text. Many CPOE systems have the capability to capture log information such as who overrides the alerts, what the reason is and the level of the alert that was shown. Some clinicians may not want their name to come up on an override report. It could be speculated, that in some instances, users may consider free-text to avoid this level of documentation. Close supervision of CDS overrides and free-text entries, well designed and tiered CDS rules, and other CDS enhancements are needed.

5.2.4. Training for users

Successful implementation of CPOE/e-prescribing, EHR and Computerized Medication Reconciliation depends on appropriate training of staff to use these systems. Without effective training, free-text order entries become the "default" workaround as clinicians become fatigued by constraints of the system. Our results show that different types of providers and clinical settings had different free-text rates and misspelling rates. For example, 31.5% of RNs's medication order entries were free-text and 22.8% of these entries included misspellings. RNs are typically not the prescribers as their order entries require physician authorization or "sign off". In some clinics, nurses, physician assistants, and pharmacists assist with the task of medication reconciliation. Nevertheless, these providers as well as physicians all play a role in medication order entry, additional and perhaps tailored training for the appropriate use of CPOE is necessary.

5.3. Limitations of the study

This study has several limitations. First, it was conducted in the ambulatory setting in a single institution. The results may not be applicable to other clinical settings and institutions. Second, some information (e.g., demographic information for non-physicians) was missing from our data set. Third, in this study we only focused on hypoglycemic agents. Future studies are needed that include a wide range of medications, beyond hypoglycemic agents and their outcomes evaluated. Fourth, our study database did not contain information regarding whether the free-text medication order entries were true clinician orders or just "placeholders" which were used to document medications the patient was taking. This is another area that needs further investigation. Fifth, our study did not follow up with the 84 patients that had untriggered DDI alerts in their medication records to determine if any harm was incurred. The major concern was the difficulty in proving any direct correlation between cause and effect, because of adverse effect underreporting, medication adherence, and other non-medication related causes of hypoglycemia (such like those due to insufficient food intake and excessive exercise), would be difficult to account for. However, establishing actual harm caused by free-text in future studies could motivate prescribers to forego uncoded entry. Lastly, we provided a descriptive analysis on usage patterns of free-text among physicians. Their characteristics may be useful for others when determining baseline measurements and system usability. As a next step, it would be interesting to compare these characteristics and order habits/patterns between providers that use free-text and those that do not. It is worth noting that Zheng et al[17] found a statistically significant increase in free-text order entry by male providers. Similarly, it will be worthwhile to compare patient's characteristics between patients who have free-text medication orders and those who do not, and to investigate, for example, whether free-text entries occur more frequently in a specific patient population, in an attempt to isolate these high risk groups.

6. Conclusion

Although evidence has shown CPOE can reduce medication errors, many benefits of its use cannot be achieved if medication orders are entered using free-text. Our study demonstrated that free-text order entry is common, varying in different types of clinicians and clinical settings, and may cause harm. This is especially true for medications which belong to "high risk" categories. Reasons for free-text order entries are multifold and complex. Solutions will require strong leadership and policy to enforce structured order entry, ongoing improvement in user-interface design, improved training for users, close supervision of computerized CDS overrides, and strategies for maintaining a complete medication list.

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