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RESEARCH ARTICLE

Potential medication errors associated with computer prescriber order entry

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Abstract *Introduction* To assess the frequency of medication errors (ME) induced or enhanced by computerized physician order entry (CPOE). Error type, drug classes involved, specialty, patient outcome and system failures were also evaluated. *Methods* Observational quantitative study in a large tertiary care medical center over March 2012 3 years after CPOE implementation. Pharmacists detected ME associated with CPOE (those that wouldn't have occurred if the clinician had prescribed manually) and unassociated in pharmacological treatments in inpatients of 13 specialties (421 beds). Main outcome measured were ME associated and unassociated with CPOE. *Results* We found 714 ME with 85.857 drug prescriptions (a 0.8 % error rate, 95 % CI 0.6–0.7). Percentage of error associated with CPOE was 77.7 %. The main types of error related to CPOE were wrong medication selection (20.9 %) and improper data placement (20.3 %). Failures with medications prescribed in primary care, unavailable in the hospital pharmacy, were involved in 21.6 % of all ME. Errors involving surgical specialties were double those involving medical specialties (1.2 *vs.* 0.6 %). Most ME associated with CPOE were potential errors (90 %). During the study system failures occurred four times. *Conclusions* The use of CPOE minimises the occurrence of medication errors, however, they still occur. Most errors are associated with the CPOE technology. We therefore face a new challenge in the prevention of ME that require a change in strategy for patient safety. Continued training of prescribers, standardization of the electronic prescription programs and integration between computer applications in hospitals and with primary care should be a priority.

Keywords Computerized physician order entry system · COPE · Hospital pharmacy · Medication errors · Prescribing · Spain

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Impacts on Practice

- Safety and effectiveness of technology in healthcare ultimately depend on its human users.
- Currently we face a new challenge in relation to the prevention of medication errors that requires a change in strategies for patient safety.

Introduction

Adverse drug events have a major impact on the healthcare system. Several studies over the last few years have shown that they are largely due to failures during the ordering stage of the medication process. About one third of serious medication errors occur in this phase [1–4].

To help prevent prescription errors, computerized physician order entry (CPOE) systems have been touted as a promising strategy [5, 6]. This system holds advantages

such as immediate drug information, facilitates communication among healthcare staff, links with other programs [7–10] and has proved to be efficient in reducing treatment costs [11].

Nevertheless, in some ways this health technology might induce or contribute to medication errors different from those that occurred when clinicians used manual prescription or facilitate others already existing [12–16]. Negative consequences resulting from CPOE implementation could include informational technology (IT) failures, loss of registered data, and lack of knowledge or distrust of the system by health professionals.

To define these new kinds of unintended errors that are emerging following the implementation of new health technologies including CPOE a new term of *e-iatrogenesis* has been coined [17].

Few authors have investigated factors that might enhance prescription errors [18]. Koppel et al. [19] described 22 types of medication error risks facilitated by CPOE related to fragmentation of data after medication discontinuation, system integration failures, human–machine interface failures that can lead to wrong patient or medication selection, loss of data or failure to provide medications after surgery. Campbell et al. [20] identified unintended adverse consequences this system such as unfavorable workflow, paper persistence, never-ending demands, more work for clinicians, and a developed overdependence on the technology amongst others.

However, the actual incidence of new kinds of errors generated by this technology is unknown because most of the studies published are qualitative. Taking this into account we carried out the following quantitative study in order to assess the frequency of failures associated with electronic prescription.

Methods

We performed a longitudinal, observational, quantitative study in a large tertiary care medical center over 1 month (March 2012) 3 years after CPOE implementation. The implemented system provides the physicians clinical decision supports in order to facilitate drug prescribing process (alerts about drug allergy, dose range, duplications, drug interactions, etc.)

We defined as main outcome the medication errors caused or enhanced by the use of electronic prescription in accordance with the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) definition of ME as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer" [21]. We considered ME associated to CPOE those that would not have occurred if the clinician had prescribed manually.

We also evaluated error characteristics, involved drug classes and patient harm according to NCCMERP classification [21], and the effect of pharmacists being able to retrospectively review their orders (whether or not this enabled them to intercept errors during the process).

We carried out this study in a major urban tertiary-care teaching hospital with 1.400 beds. CPOE was used from 2009 by clinicians and integrated with the pharmacy's and nurse's lists. On average 200.000 medication prescriptions monthly are electronically prescribed and clinically reviewed by pharmacists.

We used a direct-observation method of pharmacological treatments prescribed electronically by clinicians to measure error rate. All medical orders are available online in the pharmacy department where investigators detected prescription errors.

Statistical analysis

We designed a database that reflected the content of the data collection form. This database then established the range and possible values of the data entry matrix, as well as the different coherency rules between variables. The quality of information received was controlled by the realization of an exploratory data analysis whose aim was to detect discrepant values, either absent or out of range, the distribution of the principle study variables, as well as any possible transformations.

The descriptive statistics were presented in a summary of the continuous variables, of which the following were included: mean, standard deviation, minimum, maximum, as well as first and third quartiles. For the categorical data, the absolute and relative frequency distribution was presented along with 95 % confidence intervals. All statistical tests were considered bilateral, and significant with values of $p < 0.05$. Statistical analysis was carried out with the program SAS 9.1 (SAS Institute Inc., Cary, NC, USA).

The study size was based on a week-long pilot study in which an error prevalence of 0.6 % was detected with an interval width of below 0.1 %. In this way, we calculated that with a four-week-long study we could analyse the characteristics (secondary variables) of 700 ME associated with CPOE and estimate the percentages of each error with accuracy of 95 % or above.

The fact that we did not evaluate treatments prescribed during the afternoon and night is a limitation of our study.

This study was approved by the University Hospital La Paz institutional review board.

Results

We evaluated 85.857 drugs prescriptions on wards that have a CPOE. 714 ME were detected (a 0.8 % error rate, 95 % CI 0.6–0.7). The rate of errors associated with CPOE

Table 1 Medication errors associated with computerized physician order entry

Error type	N° errors associated with CPOE	% of total errors associated with CPOE (%)
Inadequate drug allergy registration	49	8.8
Error in frequency of administration	92	16.6
Irregularly timed regimen of administration	8	1.4
Timing of administration when alternating two drugs	50	9
Single dose at the moment of prescription	7	1.3
Administration of drugs whenever patient required them	22	4
Administration of programmed single dose	5	0.9
Incorrect prescription line	287	51.8
Inadequate medication selection	116	20.9
Incorrect medication selection from an alphabetical dropdown list	34	6.1
Mismatch between regimen and medication selected	34	6.1
Inadequate medication selection due to sequential therapy	49	8.8
Duplicate drug prescription	57	10.3
Duplicate drug prescription due to entering in the prescription and free text field	53	9.6
Duplicate drug prescription in prescription field only	4	0.7
Prescription in wrong field	64	11.5
Discrepancy between medication prescribed and free-text explanation	33	5.9
Omission of drug administration due to handwritten prescription on patient flow sheet	15	2.7
Erroneous association of medications	2	0.4
Error in prescription of programmed treatments	52	9.4
Error in start–end of programmed treatments	41	7.4
Error in preoperative treatment	8	1.4
Error in perioperative treatmnet	3	0.5
Error in nursing care	40	7.2
Omitted date	38	6.8
Date not updated	2	0.4
Dosage errors	29	5.2
Incorrect dose	9	1.6
Incorrect dose prescribed by default	9	1.6
Omitted dose	4	0.7
Incorrect unit of measurement	7	1.3
Error due to drug interaction	5	1

* *CPOE* computerized physician order entry

use was 77.7 %. The remaining 22.3 % were unrelated to this system and had also occurred using manual prescription. Table 1 lists the type of errors related to CPOE and their frequencies of occurrence.

The main types of error related to CPOE were wrong medication selection (20.9 %) mostly caused by a mistake in selection from a drop down list and changes in drug administration route in sequential therapy. Another important source of error was improper data placement (20.3 %) mainly due to data entry into a wrong location (11.5 %), which means that the physician did not entered data in the right place in the program, and inappropriate drug allergy registration (8.8 %). Other types of common error were related to inappropriate use of the free-text field (15.4 %), either by duplication or discrepancies between the medications selected through the structured template and the free-text comments. Otherwise, scheduled treatments such as perioperative drug management also represented a high percentage of errors (9.4 %) (Fig. 1).

Most errors that occurred regardless the prescription method used were associated with drug doses (68.5 %), mainly due to their omission when clinicians electronically prescribed medications not available in the hospital pharmacy that had previously been prescribed by primary care physicians (86 %). However, there was a low rate of error associated with CPOE of wrong drug dose (5.2 %). Figure 2 shows the main types of errors not associated with CPOE use.

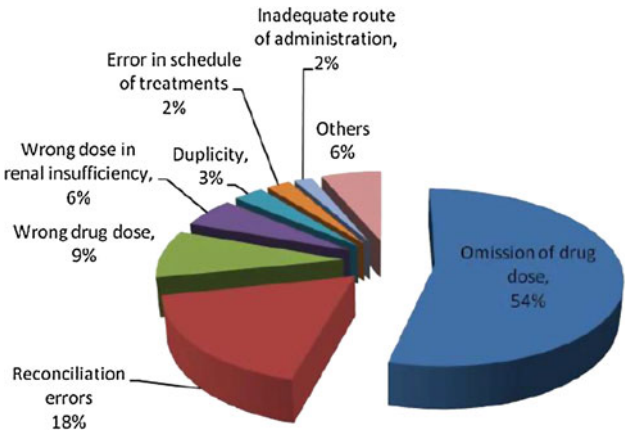

Fig. 1 Main type of errors associated with electronic prescription

Concerning the drug classes involved in prescription errors when clinicians used CPOE. Analgesics were the drug class most frequently involved (22.5 %) principally due to timing errors in medication administration (42.6 %) and failures when changing doses or route in sequential therapy (21.7 %). Antiinfectives were the second leading class involved in medication errors (17.4 %), they were mostly due to mistakes in timing the start and end of scheduled treatments (27 %) and incorrect drug allergy registration (24.7 %) (Fig. 2).

Prescription errors occurred regardless of the prescription method, mainly involved medications not available in the hospital pharmacy prescribed by primary care physicians (62.2 %), and mostly due to drug dose omission (86.9 % of them). In these cases, the program does not' provide any information through clinical decision supports included within it. In other cases clinicians manually wrote "patient′s usual treatment" in the free-text field (6.3 %). This highlights the fact that the largest error rate in global terms, related and non-related to CPOE (21.6 % of all errors detected) were due to failures in medications prescribed in primary care prior to hospitalization that the patient began taking, but which were then unavailable in the hospital.

According to different specialties, we observed that errors involving surgical orders were double those involving medical specialties (1.2 *vs.* 0.6 %) (Fig. 3).

We observed that 90 % were potential errors, namely occurring but not reaching the patient (category B^{21}). This means that those errors that reached patients (category C^{21})happened regardless of the prescription method, electronic (29.2 %) or manual (70.8 %) (Table 2).

Pharmacist's intervention intercepted 440 prescription errors (61.6 %), of which 73.3 % were resolved before the error reached the patient.

Finally, over the study period technology failures occurred four times, two of them due to the CPOE program crashing and the other two to a collapse in the link between CPOE and the automatized medication dispensing device.

Discussion

Numerous published articles have proved the efficacy of CPOE in reducing medication errors In agreement with other authors, we have found a 0.8 % error rate [5, 6, 22].

However, the implementation of this technology generates or facilitates new kinds of prescription errors that didn't occur when clinicians prescribed manually. We detected in our quantitative research a high rate of failures associated with CPOE out of all the medication errors that occurred during the ordering process (77.7 %). Despite this, there are no other quantitative published studies with which to compare our results.

Most of the errors were due to incorrect medication selection (20.9 %), errors which are specific to the electronic prescription system. This type of error can have serious consequences as there is a risk that the erroneously selected medication could be sent from the pharmacy and administered to the patients. To our knowledge few authors have described this error [19, 20], but they did not analyze their true frequency. According to our results, errors categorized as this type occurred mainly when clinicians had to make a selection from an alphabetical drop down list. For example, there was a case where the clinician mistakenly selected Ventavis® (active ingredient is iloprost used to treat pulmonary hypertension) instead of Ventolin® (active ingredient salbutamol used to treat asthma or COPD). If the error had not been intercepted by the pharmacist, it could easily have reached the patient.

We also detected failures in medication selection when prescribers modified some aspect of previous prescriptions, principally when they changed the route of administration from intravenous to oral in sequential therapy, erroneously maintaining the parenteral medication form initially prescribed. In other cases errors were due to the mismatch between a new regimen and the prescribed medication form, usually due to a tapering regimen of corticoids.

Incorrect data entry generated another frequent type of error associated with CPOE (20.3 %) as a consequence of incorrect data entry location (11.5 %) and inadequate drug allergy registration (8.8 %). Incorrectly stored data in the program may impede other health care professionals from receiving relevant information or impede the program cross-checking with other data [20, 23] which can have potentially serious consequences for patients.

Computerized physician order entry has proved to be very effective is in reducing errors related to drug allergies [24]. According to our results, these errors nevertheless persist despite the use of this technology. The incorrect

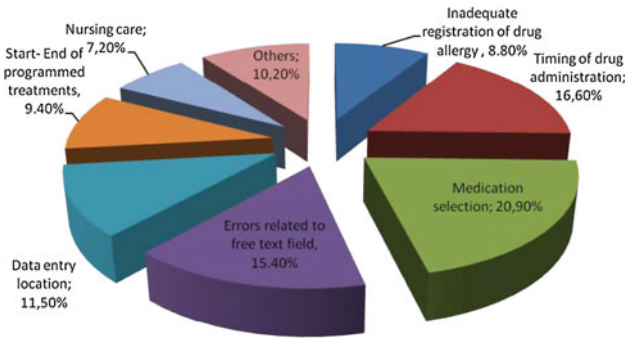

Fig. 2 Main type of errors not associated with electronic prescription

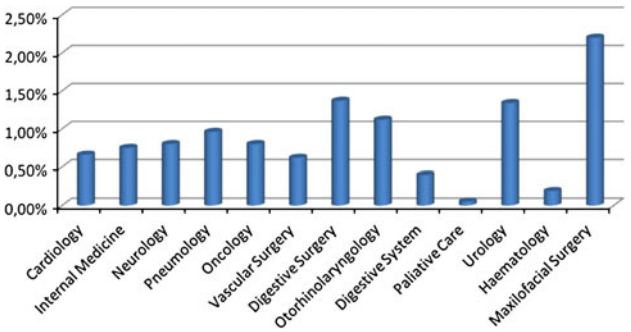

Fig. 3 Percentage of medication errors according to specialties

Table 2 Patient outcome [21]

Category	N° errors associated with CPOE	N° errors not associated with CPOE	N° errors
A	44	2	46
B	502	141	643
C	6	18	24
D	1	0	1
TOTAL	553	161	714

CPOE computerized physician order entry

* A: circumstances or events that have the capacity to cause error

* B: an error occurred but did not reach the patient

* C: an error occurred that reached the patient, but did not cause patient harm

* D: an error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm

registration of a drug allergy in the program invalidates the warning triggered by the program when clinicians prescribe a drug to which the patient is allergic.

An important advantage of the CPOE is the standardization of treatment. However, in many cases the inflexibility of the program represents an obstacle to the prescriber [12, 19]. Often, this inflexibility, the lack of program management or distrust of the electronic prescription system, leads to an overuse of the free-text field increasing the probability of error [6, 23].We found that narrative instructions in this field provoke a high percentage of error (15.4 %) due to duplication or discrepancies between the medications selected through the structured template and the provider's free text comments.

Another frequent error specific to CPOE was caused by a wrongly indicated start and end date in scheduled treatments (9.4 %). This type of error, previously described by other authors [12, 19], mainly affects perioperative therapy. Moreover, patients undergoing surgery are transferred between different wards which increases the likelihood of failures as a result of the system fragmentation.

Drug dose related errors are usually the most frequent when clinicians prescribe treatments manually [25]. In our study they represent a small proportion of errors related to CPOE, probably because the program provides the usual dose of drugs by default. Nevertheless, we have observed, like other authors [23, 26] that sometimes this theoretical advantage of CPOE may also provoke prescription failures since it encourages the clinicians to prescribe the usual dose even though the patient requires a different one.

We observed that the main drug classes involved in errors related to CPOE were analgesics, antiinfectives and cardiovascular drugs. Singh et al. [23] found results consistent with ours. Moreover, prescription of medications not available in the hospital, for which the program does not provide information, accounted for the largest error rate out of all the failures detected (both associated and not associated with CPOE use). This fact proves that, despite its advantages, the electronic prescription system has not eradicated errors related to medications prescribed previously outside the hospital in primary care. Thus, more than 75 % of these failures occurred independently of the prescription method used by clinicians.

The frequency of detected errors in surgical specialties was twice that detected in medical specialties. We found no data published on this point, but it could be due to the difficulty in prescribing perioperative treatments electronically. These errors related to therapy schedules are specific to CPOE.

We evaluated patient outcomes according to the categories established by NCC MERP taxonomy of medication errors [21]. According to our results, 90 % of the errors we detected would be coded as category B ("error occurred but did not reach the patient"). Singh et al. [23] obtained similar results to ours even though they used a different patient outcome classification in their study. It is noteworthy that one of the most severe categories reported was C type ("error occurred, reached the patient but did not cause patient ham"), the only type that occurred more frequently regardless of CPOE use. Thus, therefore it can be assumed that there were more errors included in this category that would have equally occurred if clinicians prescribed manually than those associated with CPOE.

According to users, one of the major drawbacks of electronic prescription is an overdependence on technology [12, 20]. Often in hospitals, if there is an IT failure, there is no alternative or back-up system to maintain workflow in the medication use process. Over the study period, we registered four IT failures, in two cases the CPOE program crashed and in the other two there was a break in the link between the CPOE system and the automatized dispensing medication device which interrupted pharmacy workflow.

Conclusion

Taken together, our findings show that CPOE has managed to minimize medication errors at the ordering stage. However, they do still occur after implementation, and those that do are mostly associated with the CPOE technology itself, making their characteristics notably different from classic ME when clinicians prescribed manually. In addition, the transfer of data registered can be considered as the main weak point of this technology, causing a lack of continuity in pharmacological treatments when the patient is transferred between different units in the hospital, principally in surgical patients, but also with treatments prescribed in primary care and the subsequent discrepancy with treatments prescribed in the hospital.

Therefore, we face a new challenge in relation to the prevention of medication errors that requires a change in strategy for patient safety. Continued training regarding the use of electronic prescription systems, the standardization, and the integration of such programs in hospitals with prescription methods in primary care will be priority. In this sense, further research should focus on the detection and prevention of these new medication errors at the ordering stage that will hopefully lead to optimal CPOE implementation.

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Conflicts of interest The authors have no conflict of interest.

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