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Impact of Computerized Physician Order Entry on Medication Prescription Errors in Patients Hospitalized in a Chest Diseases Ward

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Abstract

Background: Many adverse drug events are related to medication errors during the ordering process and may be preventable. Computerized physician order entry (CPOE) appears as an effective tool in reducing them.

Methods: We conducted a before-after prospective study in a chest diseases ward of an academic medical center. We compared rates of medication errors in medical orders during three phases: one before (manual prescription) and two after implementation of CPOE, at one and two months after. Secondarily we assessed error characteristics, process of medication use management and economic impact.

Results: We detected 422 medication errors in 3257 medications prescribed: 352 in manual prescription phase (34.9% error rate) versus 45 one month after CPOE implementation (4.1% error rate)-88.2% relative risk reduction ($p<0.001$) and 25 after two months (2.2% error rate)-93.7% relative risk reduction ($p<0.001$). Main causes of error using manual prescription were lapsus in the ordering stage (68%) while using CPOE were lack of technology management (66.7% after one month and 68% after two months). Errors fell significantly for all drug types when comparing electronic versus manual prescription. We also found a significant reduction of non-drug-related errors, from 14.2% without the use of CPOE to 0.8% with its use ($p<0.001$) and in the amount of time spent preparing medication in pharmacy department. On average monthly drug costs fell 30%.

Conclusions: CPOE substantially reduces medication errors and non-drug-related errors as well as improves the process of medication use management and appears to have a positive economic impact.

Keywords: Medication prescription errors; Computerized physician order entry

Background

Most of medication errors (ME), about one third of them, occur at the ordering stage of the medication process [1]. According to ADE prevention study [2], 56% of preventable adverse drug events (ADE) take place in this phase. Prescription errors occur in up to 39.1% of medication orders written for hospital inpatients [3]. Computerized physician order entry (CPOE) have proved to be promising for preventing prescription errors. This tool improves healthcare staff communication, provides drug information and facilitates clinical decisions related to treatments [4-6].

Taking into account the scarcity of CPOE studies that include respiratory patients and the high complexity of these patients' pharmacological treatments which potentially increases prescription errors, we designed the following study. Our main objective was to evaluate the effect of this technology on ME.

In addition to this, we analyzed the characteristics of the errors, cause, harm and severity, involved drugs and clinical decision supports (CDS) used by prescribers. Also, we assessed the impact of CPOE implementation on other type of error despite medication errors like patient identification, time optimization in the process of medication use and economic impact.

Methods

We conducted a before-after study in tertiary academic medical center. Medication orders prescribed on a chest diseases ward were included. Over a 3-month period pharmacists detected ME during three periods of time (of five days each): the first period was previous to CPOE implementation (manual prescription), the other two periods were chosen at one and two months after CPOE implementation.

We chose this medical specialty because the complexity of pharmacological management of these patients. They usually have concomitant diseases that increases the likelihood of ME. In this context, CPOE can be especially useful because the program provides information about drugs, access to other programs and improves communication between healthcare professionals. As well as informing the physicians about drug allergies, drug interactions, treatment modifications on certain clinical situations, and even the cost of medicines [7,8].

Study outcomes

The main outcome measured was the number of medication errors detected when using manual prescriptions versus electronic prescription method. Here, medication error is understood as"any

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preventable event that may cause harm to the patient or lead to the inappropriate use of drugs when they are under the control of health professionals or patients" [9].

At the same time we analyzed the error type, causes, harm and severity according to NCCMP classification 9, involved drugs, effect of CDS on error reduction and other outcomes related to the process of medication use such as patient identification data, medical order reception in pharmacy department, process efficiency in terms of time needed or the economic impact of CPOE implementation.

Statistical analysis

Data sources were CPOE program and nursing administration records. Statistical analysis was performed with descriptive summary measurements of continuous variables for the three study periods – before CPOE implementation, one and two months afterwards, consisting of the mean, standard deviation, median, minimum, maximum, quartiles 25% and 75% and categorical data frequency distributions.

We calculated the 95% confidence interval.Statistical tests were considered as bilaterally significant with $p<0.05$. Statistical analysis of data was performed using SAS9.1 (SAS Institute Inc., Cary, NC, USA).

The primary efficacy analysis was the percentage of medication errors, compared before and after CPOE implantation, using the chi-square for independent data.

For comparison on quantitative data between two groups we used a student's t-test as a parametric test and the Mann-Whitney test as a non-parametric test, depending on the distribution of data. For comparing quantitative data between more than two groups, we used variance analysis as a parametric test and the Kruskal-Wallis test as a non-parametric test.

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

Results

We detected 422 medication errors in 3257 medications prescribed. In first phase (manual prescription) (MP) 352 errors in 1010 medications ordered (34.9% error rate), 45 errors in 1109 medications (4.1% error rate) one month after electronic prescription implementation (EP1) and 93.7% relative risk reduction (RRR) EP1 vs MP and 25 in 1138 medications (2.2% error rate) after two months (EP2), 46% RRR EP2 vs MP.

Secondary outcomes assessed were Table 1:

Error characteristics

Type: We assessed seven types of errors which are described in Table 2.

Cause: Main causes were lack of drug information, lapsus, lack of patient information, lack of technology management (Table 3).

Error characteristics	Type Cause Patient outcome and severity Involved drugs Use of clinical decision support
Process of medication use management	Non drug-related errors Time management
Economic impact	Monthly drug costs

Table 1: Secondary outcomes.

Error Type	MP	EP1	EP2	P Value
Name of drug	2	1	3	ns
Dosage form	2	1	2	ns
Route of administration	38	2	0	p<0,001
Dose	156	4	2	p<0,001
Units of measurement	295	1	1	p<0,001
Timing: hour and frequency of administration	27	20	8	p<0,001
Medication order	14	18	10	ns

Table 2: Medication errors over three study periods according to type MP: phase 1 (manual prescription), prior to electronic prescription implementation EP1: phase 2 (electronic prescription), one month after electronic prescription implementation PE2: phase 3 (electronic prescription), two months after electronic prescription implementation ns: not statistically significant.

	Total errors	Lack of drug information	Lapsus	Lack of patient information	Lack of technology management
MP	352	136	213	3	0
EP1	45	7	5	3	30
EP2	25	4	4	0	17

Table 3: Medication errors by causes MP: phase 1 (manual prescription), prior to electronic prescription implementation EP1: phase 2 (electronic prescription), one month after electronic prescription implementation PE2: phase 3 (electronic prescription), two months after electronic prescription implementation.

	Potential	Reached the patient without harm	Required monitoring	Temporary harm and required intervention	Temporary harm that prolonged hopitalization
MP	323	26	2	1	0
EP1	39	5	0	0	1
EP2	22	3	0	0	0

Table 4: Numbers of errors by patient outcome MP: phase 1 (manual prescription), to electronic prescription implementation EP1: phase 2 (electronic prescription), one month after electronic prescription implementation PE2: phase 3 (electronic prescription), two months after electronic prescription implementation.

Figure 1: Prescription errors by drug class.

Errors in phase 1 mainly were due to lapsus in the ordering stage (68%) (MP vs EP1 p<0,001, MP vs EP2 p<0,001), and lack of drug information (38.6%) (MP vs EP1 p<0,001, MP vs EP2 p<0,001). Whereas once CPOE was implemented were mostly due to lack of knowledge and technology management, 66.7% of them in phase 2 one month after CPOE implementation, and 68% in phase 3 after two months.

Patient outcome

More than 80% of errors did not reach patient regardless of the prescription method used (Table 4). Four errors caused patients harm, three during the MP phase and one in the EP1 phase. Of these, two required monitoring, one required intervention to preclude harm and another prolonged hospitalization. Data show an important reduction of errors when passing from manual to electronic prescription, even though results were not statistically significant.

Involved drugs

The number of all the drug group errors fell significantly when comparing electronic versus manual prescription. Figure 1 shows main drug classes involved in errors.

Usefulness of clinical decision support: The program includes CDS which warn the physicians when there are any drug interactions or possible allergic reactions. In phase 1 there were three errors related to drug allergies and ten drug interactions. In the electronic prescriptions phases there weren't any drug allergy related errors or drug interactions.

Process of medication use management

Non-drug-related errors: There was a significant reduction of non-drug-related errors like wrong patient identification data or failure in the reception of prescriptions in pharmacy department (0.8% when using electronic program versus 14.2% when using manual prescription).

Time management: We detected an important reduction in the amount of time spent preparing medication in pharmacy department (Figure 2).

As a result, medication was delivered significantly earlier to the ward (EP1 vs MP p<0,001 and EP2 vs MP p<0,001).

Economic impact

According to data registered in pharmacy department, monthly costs were reduced by 30% on average when comparing ten months after CPOE implementation with the same period prior to this new technology being introduced.

Discussion

CPOE proved to reduce prescription failures in patients with respiratory disease. Errors fell from almost 35% when pharmacological treatment was handwritten to 2.2% after two months (RRR=93.7%) (p<0.001). Ammenwerth et al. [10] analyzed ME reduction once CPOE was implemented. Of 25 studies evaluated, 23 showed a significant relative risk reduction of between13% to 99%. The authors justify this variability by the differences in the CPOE programs, definitions of the measured outcomes and study designs. Those that used programs that included CDS obtained similar results to ours. However, other authors obtained worse results, most of them in paediatric or intensive care patients [11-13].

CPOE has shown a significant decrease in errors related to four variables: route of administration, doses, unit of measurement and frequencies or timing of medication administration.

Wrong route administration of drugs can have fatal consequences. In respiratory disease several cases of mistaken intravenous administration of salbutamol instead of inhalation have been notified. As a result, patients received 5-10 times the required dose of the drug with serious cardiovascular complications [14]. According to our data, errors in the route of drug administration fell from 3.8%, until they were non-existent by the end of the study, probably because the box relating to the administration route is obligatorily completed.

Most errors when physicians prescribe are related to dosage [15]. In our study the incidence was significantly reduced when implementing CPOE more than any other type of error (15.4% MP vs 0.2% EP2) (p<0.001)because the program includes the usual dose by default. Moreover, the program provides recommendations about dosage in renal or hepatic impairment, maximum dose, etc, that could contribute to this suppression. Nevertheless, Shulman et al. [16] detected an increase of dosing errors probably due to the electronic program not' including CDS or it being carried out on critical patients.

Concerning failures related to the measurement unit of drugs, an error of this type can have dangerous effects (e.g. a drug prescribed in mg instead of mcg would result in the administration of a dose 1000 times the recommended). These errors occur frequently in intravenous administration, in a route change usually in perioperative medication management or in sequential therapy. We observed a significant errors reduction related to drug unit measurement, from 30% in the MP phase to 0.1% in EP2. However, despite their relevance to patient safety, we have not found any other study that analyzes this ME.

Medication errors associated with time or frequency of administration decreased significantly once CPOE was implemented (2.7% on MP phase to 0.7% on EP2 phase). Other authors agree with us on this issue b [17].

Concerning the causes of prescription errors, lapsus was the main cause in the MP phase (21.1%) followed by ignorance about drugs (13.5%). Franklin et al. [3] similarly identified lapsus (57%)

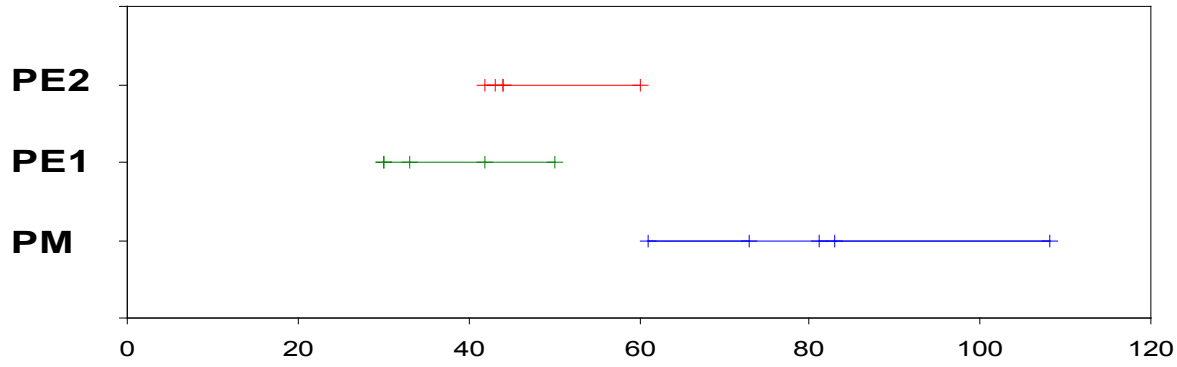

Figure 2: Time (min) evolution in the preparation of medication for patients hospitalized in the chest disease Ward. MP: phase 1 (manual prescription), corresponding to study period prior to electronic prescription implementation EP1: phase 2 (electronic prescription), corresponding to study period one month after electronic prescription implementation PE2: phase 3 (electronic prescription), corresponding to study period two months after electronic prescription implementation EP1 *vs*MP p<0,001 EP2 *vs* MP p=0,001.

and ignorance about drugs as the main causes of prescription error (35%). However, most of errors in the EP phases were due to lack of technology management. Our data proved that there was a significant reduction of medication errors due to all four of the analyzed causes when physicians used CPOE.

In this study 80% of errors didn't reach patients regardless of the prescription method used. There are not many articles that asses its impact of CPOE on adverse drug events, probably due to the difficulty of identifying them. These can be confused with the progression of the disease and it is not easy to associate it with a taken drug. Wolfstadt et al. [18] carried out a review on studies evaluating the effect of CPOE on the rates of ADE. Ten studies were included and half of them observed a significant reduction.

Our study shows that errors mainly involved cardiovascular drugs (24.4%) more than 70% due to lack of drug information. This error rate decreased significantly using CPOE thanks to the information provided by the program. However other authors [19,20] detected that prescription errors more often involved antimicrobials, probably because these studies didn't include medical neumology, the drug management of which they have a high degree of knowledge about.

CPOE have demonstrated to be an effective tool particularly in the prevention of medication errors related to drug allergy. When physicians prescribe a drug to which the patient is allergic a warning is triggered, thus avoiding the prescription error. Other studies agree with us on this issue[20,21].

One major source of errors is the mismanagement of medical orders that leads to another type of failures that we called administrative errors, which can affect patient identification data or the availability of treatments in the pharmacy department which delays or prevents their checking and validation by pharmacists. Both can have potentially harmful consequences. We found asignificant reduction after implementing CPOE, from 14.2% when using MP, to 0.8% when using PE. However,despite the relevance of these failures, we found no data with which to compare ourselves to other studies.

Moreover CPOE improves the overall process of medication use. Optimization of the first ordering stage indirectly optimizes subsequent stages in the run up to the drug administration stage. In our study there was a significant reduction in the time it took to prepare medication in the pharmacy department and consequently the delivery time to the ward was advanced.

Finally, concerning the cost- benefit ratio associated with CPOE, we observed a significant drop in costs after CPOE implementation. On average monthly drug spending fell 30%. However, due to the complexity of the medication process and the fact that many factors exert an influence, this reduction in drug spending cannot only be attributed to the CPOE. Other studies have also observed to reduce medication costs, improving the efficiency of hospital workflow [22] Kaushaletal. [23] investigated the return on investment (ROI) in an academic medical center. Their study showed significant money savings by implementing the CPOE system, particularly if they have high level of CDS. Renal dosing guidance, adverse drug events prevention through drug dose, allergy or interactions nurse time utilization, specific or expensive drug guidance or intravenous to oral guidance were found to be the most financially beneficial interventions. Our study showed similar results. Nevertheless, other authors [24] found that CPOE were associated to a modest ROI which could be attributable to the lack of CDS in the electronic prescriptions system evaluated. According to economic studies, there are contradictory results in terms of costs and benefits estimates in different hospitals were COPE was analyzed [25].

Taking together, our findings show that CPOE reduces medication errors, principally those related to dose, route of administration, drug measurement units and time or frequency of administration. The main causesof error in the manual prescription were lapsus or ignorance about drugs. Both causes were reduced significantly by using electronic prescribing. The most frequent source of errorusing CPOE was the ignorance and poor management of the program. In addition, CDS integrated into the program reduce prescription errors, particularly those related to drug allergies.

Furthermore, this technology improve the management process of medication use, reducing administrative errors and shortening the time needed for preparing medication in the pharmacy department. Additionally, drug spending was reduced once CPOE was implemented which might also be related to this technology.

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