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Administration/Outcomes

Computerized physician order entry in the cardiac intensive care unit: Effects on prescription errors and workflow conditions☆,☆☆

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ABSTRACT

Purposes: To evaluate the effects of a computerized physician order entry (CPOE) system in the cardiac intensive care unit by detecting prescription errors (PEs) and also to assess the impact on working conditions.
Methods: A longitudinal, prospective, before-after study was conducted during the periods before and after the implementation of the CPOE system. Clinical pharmacists were responsible for the registration, description and classification of PEs, and their causes and severity, according to an international taxonomy. Professionals were also surveyed for their opinion, concerns, and level of satisfaction.
Results: A total of 470 treatment orders containing 5729 prescriptions were evaluated. The CPOE resulted in a marked reduction in the number of PEs: error rate was 44.8% (819 errors among 1829 prescriptions) with handwritten orders and 0.8% (16 among 2094 prescriptions) at the final electronic phase ($P < .001$). Lapses were the main cause of error in both prescription methods. Most errors did not reach the patients. Errors related with the computerized system were scarce. Most users were satisfied with many aspects of this technology, although a higher workload was reported.
Conclusions: Computerized physician order entry in the cardiac intensive care unit proved to be a safe and effective strategy in reducing PEs and was globally well received by professionals.

1. Introduction

Computerized physician order entry (CPOE) can contribute to hospitalized patients safety by reducing common medication errors, mainly in the prescription phase [1,2]. Organizations that monitor the quality of health care recommend the implementation of electronic prescription (EP) in this setting [3].

Patients admitted to the intensive care unit (ICU) are particularly vulnerable to prescription errors (PEs) because of the presence of multiple risk factors [4]. However, the use of CPOE in ICUs is still limited for several reasons: the complexity and variability of the patient's clinical status, which requires frequent changes in treatment orders; the possibility of committing new medication errors by misuse of computer media; and the workflow disruptions [5,6].

Although there have been several publications regarding its use in the pediatric intensive care setting [7], only few authors have specifically evaluated the effects of CPOE among adult patients admitted to the ICU [8–10]. While analyzing these studies, it could be observed that disparity in results was probably caused by the incorporation of the different clinical decision support systems (CDSS), the degree of local adaptation in computer programs, and the development of the implementation schedule. Moreover, the evidence of its impact on clinical outcomes is limited. Thus, the usefulness of CPOE in the critical care environment remains controversial.

Despite the current recommendations [11], we have not found any evidence regarding their effectiveness in nonsurgical acute cardiac patients or the official data on the degree of implementation in cardiac ICUs. These units usually assist patients with very specific cardiac pathologies. They are characterized by the high degree on standardization and formalization of their treatments. It could lead to the feeling that CPOE may not be necessary caused by a lack of PEs. Therefore, this environment appears as a challenge to explore the CPOE utilities.

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We aimed to evaluate the effects of a CPOE system, by detecting PEs, their frequency, and their type and severity, including unintended technology-related errors. We also wanted to assess the impact of EP on the working conditions and on the level of satisfaction of the personnel involved in its use.

2. Materials and methods

2.1. Setting

La Paz Hospital, a tertiary care university center in Madrid, Spain, has been provided with an EP system (Farmatools Dominion; Global Dominion Access SA, Bilbao, Spain), which has been implemented in medical and surgical units since 2009. Acute cardiac care is carried out in a 9-bedded ICU, whose medical staff is composed of 2 senior cardiologists and 3 residents. There is an average of 800 annual admissions in this unit. It is the first experience of implementation of this CPOE system in the intensive care setting at our hospital.

2.2. CPOE implementation

FarmaTools Dominion was connected with the hospital information network and equipped with a moderate level of CDSS, such as information on drugs, predefined dose, maximum dosage, and need for dose adjustment. Alerts about duplicities, potential interactions, and allergies are also available. Over the years in our hospital, this system has been refined through user feedback.

Before the CPOE implementation in the cardiac ICU, a total of 25 therapeutic protocols were incorporated into the electronic prescribing system according to the most prevalent clinical situations (ie, noncomplicated acute coronary syndrome, congestive heart failure, therapeutic hypothermia for patients resuscitated from out-of-hospital cardiac arrest, malignant arrhythmias, cardiogenic shock, etc). The staff followed a training program on the management of the computer system for 8 hours. Besides, nurses had also the opportunity to gain knowledge regarding drug dispensing sheets. There were no further interventions once the CPOE was activated.

2.3. Study design

A longitudinal, prospective, before-after study was conducted to analyze treatment orders made during the periods before and after the implementation of the CPOE in the cardiac ICU. It was developed from June to December 2012 and had 3 prespecified sampling stages of 21 consecutive days each. The first stage corresponded to a conventional manual prescription (MP) before CPOE implementation (control group). The second and third stages took place just before the completion of 1 month (EP1) and 3 months (EP2), respectively, since CPOE was started (experimental groups, Fig. 1).

Only the morning shift prescriptions were included because most health practitioners who attended the training program usually work in the morning shift. Similarly, the morning shift has the largest amount of drug prescriptions. In the 9-bedded unit, it was estimated that the number of treatment orders to study each day would be from 6 to 8, with an average of 10 to 15 drugs per patient. Study protocol was approved by the ethics committee of the institution. The informed consent was considered unnecessary.

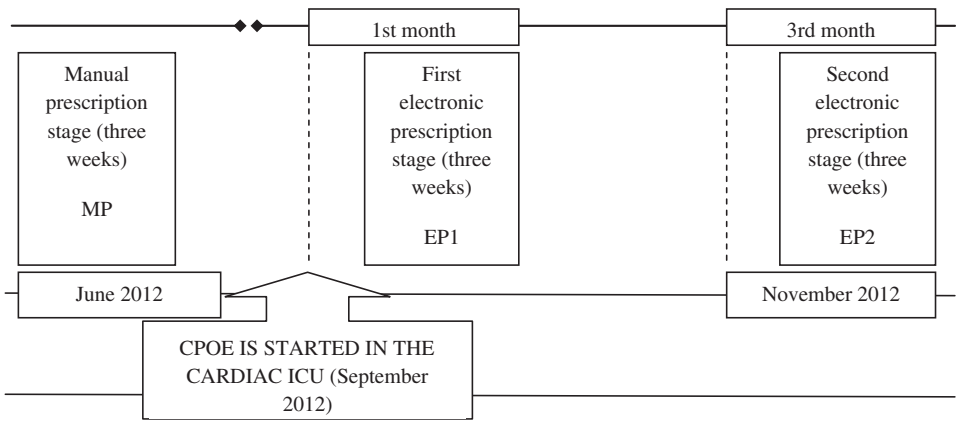
2.4. Outcomes

The main end point measure was the number of PEs identified when using EP vs MP method. Characteristics of the error, types, possible causes, and severity were explored as secondary variables following the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) taxonomy [12]. Throughout the 3 study periods, ICU-independent pharmacists analyzed the treatment orders in the course of their daily work. They did not participate in morning rounds and were not involved in drug prescription. The pharmacists were not blinded regarding the prescription method given the difficulty to mask the manual and electronic orders.

The pharmacists were in charge of registering, describing, and classifying errors as illegible, wrong, or omitted data. The specific types of error explored were as follows: drug name, pharmaceutical form, dosing (figures and units of measure), administration route, dosage interval (frequency of administration), known drug allergy, and important drug-drug interactions. In addition, prescribed drugs, effect of CDSS on error reduction, errors with the date or patient identification, and prescribed nursing care were checked.

On the other hand, those errors that would not have occurred if the clinician had prescribed manually were considered as CPOE-related errors. In this category, the following were included: improper selection from dropdown menu, errors in scheduled treatments, double prescriptions, and discrepancies in the free-text field. They were carefully checked for in the EP stages.

The degree of severity of errors was assigned by the pharmacists after reviewing patient clinical records according to NCC MERP taxonomy [12]. If needed, the pharmacist contacted the medical or



MP indicates manual prescription; EP, electronic prescri ption; CPOE, computerized prescription order entry; ICU, intensive care unit.

Fig. 1. Sampling stages and timing of implementation of CPOE.

nursing team of the unit within 24 hours after prescription. Several possible causes of errors were mainly distinguished: lapses due to oversights (for instance, when a drug is wrongly selected from a menu due to a similar name), lack of drug information (for instance, ignorance about drug-drug interactions), illegibility, and misuse of the computerized program (for instance, ignoring alerts).

One month after the last stage of the study, the entire medical and nursing staff in the ICU were surveyed to know their opinion, concerns, and level of satisfaction regarding CPOE implementation. The staff members were invited to qualify as "poor, fair, good, or very good" a total of 17 different aspects of this technology and to point main advantages and disadvantages with respect to the previous MP method. They could also do suggestions to improve CPOE performance and facilitate work conditions in cardiac ICU environment.

2.5. Statistical analysis

Data sources were the CPOE program and the nursing administrative records. Statistical analysis was performed with descriptive summary measurements of continuous variables for the 3 study periods including mean, SD, median, and quartiles 25% and 75% according to data distribution. If appropriate, 95% confidence intervals (CIs) were calculated. Statistical tests were considered as bilaterally significant with $P < .05$. Statistical analysis of data was performed using SAS 9.1 (SAS Institute Inc, Cary, NC).

The primary efficacy analysis was the percentage of medication errors, compared before and after CPOE implantation, using the χ^2 for independent data. The estimated risk reduction was performed using a Poisson regression analysis in the framework of generalized linear models. For all other purposes, qualitative data were compared using the χ^2 test. When comparing 2×2 tables, we used the Fisher exact test. For comparison on quantitative data between 2 groups, we used a Student t test as a parametric test and the Mann-Whitney test as a nonparametric test, depending on the distribution of data. For comparing quantitative data between more than 2 groups, we used the Kruskal-Wallis test as a nonparametric test.

3. Results

A total of 470 treatment orders were analyzed, of which 158 corresponded to MP (43 patients), 142 to EP1 (44 patients), and 170 to EP2 (50 patients). The set included a total of 5729 prescribed drugs: 1829 during the MP, 1806 in EP1, and 2094 in EP2. There were no significant differences in the number of drugs evaluated between the 3 periods (P, nonsignificant). The average number of drugs prescribed per patient and day was 11.5 in MP, 12.7 in EP1, and 12.3 in EP2. The characteristics of patients whose treatments were evaluated are shown in Table 1.

We found errors in 895 drug prescriptions (15.6% of 5729; CI, 14.7%-16.6%), distributed as follows: 819 in MP (44.8%; CI, 42.5%-47%), 60 in EP1 (3.3%; CI, 2.5%-4.2%), and 16 in EP2 (0.8%; CI, 0%-1.3%). This difference was significant ($P < .001$) when comparing MP with each of the EP stages. A total of 41 drug prescriptions had more than 1 PE (38 in MP and 3 in EP1). The risk of error during MP stage turned 13 times higher vs EP1 and 52 greater vs EP2. Thus, the introduction of CPOE resulted in a relative risk reduction of error of 92% and 98% in the 2 experimental periods, respectively.

We found statistically significant differences in error rates between EP1 and EP2 in the next types of error: pharmaceutical form (0.4% in EP1, no errors in EP2; $P = .002$), dose figures (0.8% in EP1 vs 0.2% in EP2; $P = .01$), and dose units of measure (0.3% in EP1, no errors in EP2; $P = .01$). The differences were not statistically significant in errors related to the drug name, the route of administration, and the dosage interval.

When comparing MP with EP2, we observed a statistically significant reduction ($P < .001$) in 6 error types at the end of the study: drug name, pharmaceutical form, dosing figures, dose units of measure, administration route, and dosage interval (Table 2). In the MP stage, we found a huge number of errors particularly in dosage and route of administration. Errors in dosage with handwritten orders were mainly caused by omitted data (category 70.1 from the NCC MERP taxonomy): omitted dosage figures (304 of 318) and omitted units of measure (274 of 286). Errors in the route of administration were also caused, in most cases, by omitted data (145 of 160 in the MP stage; category 70.7.6 from the NCC MERP taxonomy). The EP achieved a marked reduction in errors of omission. There were 36 errors consisting of illegible data (category 70.14 from the NCC MERP taxonomy), all of them with manual orders.

Table 1
Patient characteristics whose treatments were evaluated

	Sampling stage (patient-days)			P	
	MP 158	EP1 142	EP2 170	MP vs EP1	MP vs EP2
Age (y), mean ± SD	65.1 ± 14.1	63.3 ± 15.2	67.9 ± 15.6	NS	NS
APACHE II score at admission, mean ± SD	12.6 ± 7.6	10.8 ± 8.5	12.3 ± 9	NS	NS
CICU mortality (%)	6.9	4.5	8	NS	NS
LOS, median (interquartile range)	3 (1-6.5)	3 (2-4)	2 (1-3.75)	NS	NS
Patient-days in mechanical ventilation (%)	32.2	40.1	41.1	NS	NS
Patients with renal failure (%)	30.2	20.4	22	NS	NS
Drugs prescribed per patient-day, mean ± SD	11.5 ± 1.1	12.7 ± 1.7	12.3 ± 1.2	NS	NS
Intravenous perfusions per patient-day, mean ± SD	1.5 ± 0.1	1.55 ± 0.1	1.9 ± 0.2	NS	NS

MP indicates manual prescription stage; EP1, first stage of EP; EP2, second stage of EP; APACHE II, Acute Physiology and Chronic Health Evaluation; CICU, cardiac ICU; LOS, length of stay in CICU; NS, not significant. Renal failure is creatinine clearance less than 50 mL/min.

Most errors, 96% in MP and 93% in each EP stage, did not reach the patient, that is, circumstances capable of causing errors without harm ("minor") or "potential and intercepted" PEs (categories A and B in the NCC MERP taxonomy, respectively). During the study protocol, 34 errors that reached the patient without causing harm were detected (category C, also called "nonintercepted potential adverse drug events"), and 29 of them (85%) occurred in the MP period. One error, which also occurred under MP, required the monitoring of a patient who received peripheral intravenous parenteral nutrition administrable only by central line (adverse drug event without harm).

The main causes of analyzed errors were as follows: lapses due to oversights when prescribing, lack of drug information, illegible handwriting, and misuse of computer system. Most of the errors in the 3 stages were caused by lapses (90% in MP, 75% in both electronic stages; MP vs EP1: $P < .001$, MP vs EP2: $P < .001$). However, once CPOE was implemented, errors caused by lack of drug information increased in step EP1 compared with the ones in MP (21% vs 4%, $P < .001$). Similarly, although there were few in absolute numbers, we found a statistically significant difference in the proportion of errors in EP2 (25%) compared with the one in MP and in EP1 (5% and 3% respectively, $P < .001$) because of the misuse of technology.

With regard to the drugs, those most commonly prescribed (cardiovascular and hematologic drugs, which were together 53% of the prescriptions) had the lowest errors rates (11% and 15%, respectively). On the contrary, the error rate was significantly higher for low-frequency drugs: 33% for respiratory drugs (3% of prescriptions), 29% for dermatologic drugs (1% of prescriptions), and 66% for genitourinary system drugs (0.3% of prescriptions). We did not

Table 2
Number and type of errors during study stages

Type of error	MP, n	Examples of error in handwritten orders[a]	EP1, n	EP2, n	Examples of error in electronic orders[a]	*P*	
						MP vs EP1	MP vs EP2
Drug name	9	Illegibility in all cases	3	0	Wrong selection from a dropdown menu: loratadine instead of lorazepam	<.14	<.001
Pharmaceutical form	29	Wrong data: for patients with nasogastric tube, aspirin coated tablets was ordered instead of uncoated tablets or parenteral form (20 of 29 cases)	8	0	A form of bromazepam not available in the hospital (7 of 8 cases)	.001	<.001
Route	160	Omitted data (145 of 160 cases) Illegibility (4 cases) Oral instead of intravenous route (11 cases)	12	5	Oral instead of intravenous route (14 cases)	<.001	<.001
Dose (figures)	318	Omitted data (304 of 318).	15	5	Omitted data (14 cases). Wrong data: trailing zeros (3 cases) and 0.5 instead of 50 (1 case)	<.001	<.001
Dose (units of measure)	286	Omitted data (274 of 286) Milliliters instead of milligrams (8 cases)	6	0	Omitted data in all cases	.001	<.001
Dosage interval	27	Wrong frequency of administration (2 cases lower and 7 cases higher than usual)	3	3	Wrong frequency of administration (2 cases: alerts were ignored)	<.001	<.001

EP1 indicates first stage of EP; EP2, second stage of EP; *n*, number of errors.
[a] A few examples of errors consisting of wrong data are shown; most of the remaining errors were omitted or illegible data.

found differences between both prescription methods regarding pharmacologic class.

In our study, 17 CPOE-related errors (in 3900 prescribed drugs; 0.4%) were identified. We found a case of improper drug selection (fluid therapy) when a wrong option was chosen by misuse of the computer system. Duplication of a drug happened 3 times in MP and once in EP1. The software alerts the prescriber when a drug is repeated on the same day, but this error may be common with electronic methods because many of these alerts are deliberately ignored when they are considered irrelevant. We also found four errors in the scheduling (in the beginning and in the end) of treatments, 2 in each electronic phase vs 1 in MP. There were not statistically significant differences when comparing these types of CPOE-related errors with the ones in MP phase. The discrepancy with free text section, which is an exclusive error on electronic systems, happens when a written order in that free-text section is contradictory at least partially to another that was selected from a dropdown menu. In our study, we detected 5 cases in EP1 and 1 in EP2.

The use of predefined protocols increased during successive EP stages: 346 (19.2%) of 1806 drugs in the EP1 and 854 (40.8%) of 2094 drugs in EP2. In parallel, the incidence of PEs decreased. There were no episodes of drug allergy or severe drug-drug interactions throughout the 3 study periods, but the record of allergies was poor in 8% of handwritten orders vs none in both EP stages. Patient identification data were always correct, but 7% of treatment orders in MP showed mistakes in the date of treatment.

With respect to the impact of CPOE implementation on the workflow, all of the professionals surveyed (27 physicians and 20 members of nursing staff) answered the questionnaire that was given to them. Most of them rated as good or very good not only the accessibility to the EP program but also the overall performance and other 13 aspects regarding CPOE implementation. Nevertheless, when asked about the workload, it was considered negatively by 74% of physicians (opinion fair or poor) and by 17% of the nursing staff (Fig. 2).

Our CPOE program incorporates CDSS, which had been designed to prevent medication errors. When asked about them, most of the professionals were satisfied with their capabilities. In reference to the selection of drugs, the scheduled treatments, and the design of the dispensing sheets, nurses had a more favorable perception. Regarding the predefined dose, the predefined protocols, the associated texts, and the recorded allergies, physicians qualified them more positively.

The legibility of orders provided by the system was rated good or very good by all respondents in both groups of professionals. Legibility, traceability, and standardization of treatment protocols were the most appreciated by physicians. The disadvantages of the CPOE most commonly perceived by physicians in this setting were the increased time spent in the ordering stage and the overdependence on technology. Regarding the nursing care indicated in the electronic order process, discrepancies were evident: 65% of nurses felt it was fair or poor compared with 33% of physicians (Fig. 2).

When asked for how to improve the EP program, most of the physicians highlighted the need to simplify the prescription process through increasing the number of workstations, either acquiring mobile devices or, alternatively, setting a computer terminal in each patient's room. Nursing staff expressed their preference for a better standardization of treatments and a greater letter size in the printed dispensing sheet.

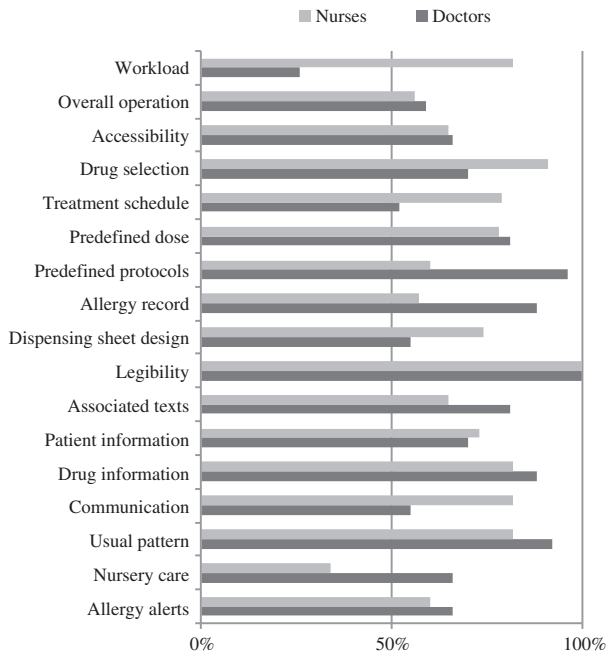


Fig. 2. Professionals' opinion: percentage of respondents who rated as “good” or “very good” several aspects of EP.

4. Discussion

Prescription and administration are the most vulnerable stages of drug treatment process. In recent years, many studies on medication errors in patients admitted to ICUs have turned their attention to those errors that occur in the administration phase [13,14]. However, we have focused on PEs, which are most likely to be prevented by the technological tool we are considering, that is, the EP.

The number of PEs, the primary end point of our study, decreased markedly by introducing CPOE compared with the previous manual method. The relative risk reduction in PEs reaches 92% after 1 month and 98% after 3 months, which indicates that a learning curve could take place. At the end of the study, the reduction was significant for the 6 error types analyzed: drug name, pharmaceutical form, dosage, units of measure, route, and frequency of administration. We obtained these data after evaluating 5729 prescriptions from 470 treatment orders in the acute cardiac care unit of our institution, where nonpostoperative cardiac patients are attended.

We did not find data about CPOE use in other similar cardiac ICUs, despite the fact that this tool is strongly recommended [11]. We have avoided comparing our results with those from pediatric intensive care because there are many factors that make this environment very different from ours: patients, more usually managed clinical situations, prescribed drugs and staff. Thus, we have to compare them with those obtained in general ICUs or in surgical ICUs where adult patients were treated [8,9]. The CDSS, the training program, and the conducted CPOE implementation process may have influenced the differences between our results and those obtained from previous studies.

Some of these studies have shown a less strong but equally significant reduction in PEs. Shulman et al [8] prospectively analyzed 3465 prescriptions in 387 treatment orders from a 20-bed general ICU during predetermined phases 6 months before and 8 months after the adoption of a commercial EP program. They found a modest reduction in PEs rate, which fell from 6.7% to 4.8% ($P < .04$) probably because of a limited degree of CDSS.

Colpaert et al [9] conducted a prospective cross-sectional study on a surgical ICU equipped with CPOE where they compared electronic with conventional MP. These authors evaluated 2510 prescriptions for 160 patient-days and found that PEs were reduced by 87%, from 27% with handwritten orders to 3.4% with the electronic program ($P < .001$). Their results were more similar to ours using a locally adapted EP system with a moderate degree of CDSS.

In our study, none of the patients experienced harm and most medication errors with both prescription methods did not reach them. In the MP stage, an error resulted in patient monitoring. This error could not be intercepted by the pharmacist, and it occurred because a wrong product was prescribed, which would have been less likely with the CPOE because of the alerts system. However, that almost all errors had not reached the patient does not detract from the usefulness of CPOE in achieving a higher-quality pharmaceutical prescription. Other studies have also found a small incidence of adverse drug events among medication PEs [9,15].

Like other authors have previously described [16–18], we found that main causes of error during MP were lapses and oversights. In addition, the illegibility of treatments due to handwritten orders was frequent. Nevertheless, during the electronic stages, illegibility errors disappeared completely and those errors due to lapses decreased markedly, mainly at the expense of omission errors. Errors related to the misuse of the computer application, although being very scarce, increased in relative terms in the final phase of the EP. Therefore, an appropriate level of attention should be maintained during the prescription process.

We were concerned about possible new CPOE-related errors, although we found a low rate of them. They were probably caused by the integrated CDSS and the way its implementation was planned in the ICU [19,20]. The increasing use of therapeutic protocols developed specifically for the EP program was inversely related to the number of medication errors. The most prescribed drugs in cardiac ICU patients had the lowest error rate, regardless of the method of prescription. On the other hand, we obtained a high rate in PEs with respiratory drugs, despite our experience with noninvasive ventilation to manage respiratory diseases.

The implementation of CPOE in the cardiac ICU was globally well received by the professionals, although a higher workload was reported by the medical staff. When asked, CPOE was qualified positively by most physicians and nurses involved in its management. This fact partially agrees with the results from another study conducted in medical and surgical units in our hospital [21]. Other sites had initially experienced opposite outcomes possibly related to a lack of adaptation from the commercial version to local characteristics and a scarce training addressed to the users [22].

Our study has several limitations. First, it was specifically conducted in only 1 ICU. Therefore, the results may not be generalized to other settings equipped with different CPOE programs. Second, only the morning shift prescriptions were included, possibly avoiding PEs. The scarcity of adverse drug events in our study could indicate that a greater number of drugs should be analyzed. On the other hand, we did not take into account the clustering effect of patients having more than 1 PE. The lack of taking this clustering effect into account can dramatically affect the type and the frequency of PEs owing to the characteristics of one patient rather than to any effect of the CPOE. Finally, there could be a bias favoring CPOE outcomes, not only because of the planned implementation process but also because of the role of clinical pharmacists as responsible on detection errors. It is known that this method usually finds more PEs than studies using retrospective chart reviews and self-reports [23].

5. Conclusions

Electronic prescription in acute cardiac care is a safe practice, effective in reducing PEs and well received by professionals, but some recommendations should be considered. The peculiarities of the inpatient unit, most prevalent diagnoses, and prescribed drugs should be determined. The pharmacist should be involved particularly in safe medication practices, error reporting, and monitoring process. The performance of computer systems should be improved by adapting them locally from the acquired commercial version and by complementing it with specific CDSS. Health professionals should be given as proper and complete training as possible. The precariousness of links to other programs that provide relevant information about the patient should be kept in mind. System weaknesses as potential sources of error should be frequently reviewed and corrected with user input.

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