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RESEARCH ARTICLE

Medication prescribing errors: a pre- and post-computerized physician order entry retrospective study

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Abstract

Background The computerization of prescriptions with a computerized physician order entry contributes to securing the error-free drug supply, but is not risk-free. *Objective*: To determine the impact of a computerized physician order entry system on prescribing errors immediately after its implementation and 1 year later. *Setting* The Cardiology and Diabetology Departments at Toulouse University Hospital, France. *Method* The prescriptions were analysed by pharmacists over three 30-day periods for 3 consecutive years (N: computerization period, N − 1, N + 1). For each identified error, the prescriber was informed by a pharmaceutical intervention. The pharmaceutical interventions were counted and arranged according to the classification by the French Society of Clinical Pharmacy. Their average numbers and clinical impacts were compared for each period using t-tests and Kruskal–Wallis tests. *Main outcome measure* The average numbers of pharmaceutical interventions. *Results* In total, 12.1 pharmaceutical interventions per 100 patient days were done during the N − 1 period, 14.1 during N and 9.6 during N + 1. Among those, 3.6 (N) and 2.1 (N + 1) were related to the computerization itself, and 10.5 (N) and 7.5 (N + 1) were not. The average number of computerization-related pharmaceutical interventions significantly decreased from N to N + 1 ($p = 0.04$). The average number of classic interventions decreased from N − 1 to N + 1 ($p = 0.02$). The clinical impacts of the computerization related errors were similar to those of other errors. *Conclusion* The implementation of the computerized physician order entry induced the appearance of specific computerized-related errors, but the number of classic errors decreased. The entry-system related errors were not more severe than other errors, and the number decreased after 1 year.

Keywords Computerized physician order entry · Clinical pharmacy · CPOE · France · Pharmaceutical interventions · Prescribing errors

Impacts on practice

- The implementation of a computerized prescription order entry system (CPOE) causes an increased risk of prescribing errors during which health professionals must be more vigilant.
- The computerization of prescriptions reinforces the role of the pharmacist in securing the error-free drug supply.
- A CPOE favours collaboration between pharmacists and physicians.

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Introduction

The computerization of patient medication management with a computerized physician order entry (CPOE) is an important contributor to securing the drug supply. Many publications highlight the positive impacts of this type of computerization, such as a decrease in prescribing errors and adverse drug events, the elimination of transcription, and improvements to legibility and traceability [1–5]. Nevertheless, the period between handwritten and computerized prescriptions is a major change in the habits and organization of clinical departments. An increasing number of publications have reported the appearance of errors related to computerization itself [6–8]. In this study, we focus on prescription computerization using the CPOE Orbis ME® in two hospitalization departments, diabetology and cardiology. These departments were chosen because of important

developments in their clinical pharmacy. Indeed, the pharmacists are very present in these departments. They perform pharmaceutical analysis and communicate everyday with the physicians regarding prescribing errors.

Aim of the study

The aim of the study is to determine the impact of the CPOE on prescribing errors immediately after its implementation and 1 year later.

Ethics approval

This article does not contain any studies on human or animal participants. The study deals with professionals' practices and ethics approval is not necessary in France for this kind of work [9, 10].

Method

Settings and study design

This retrospective study focuses on pharmaceutical interventions (PIs) performed during the pharmaceutical analysis of inpatients' prescriptions over three 30-day periods from three consecutive years. The study was conducted in the diabetology and cardiology departments. A PI is defined as any advice or proposal of drug therapy modification initiated by the pharmacist [11]. It involves the identification, prevention and resolution of problems related to the drug therapy [12]. The PIs were used in this study to analyse the detected prescribing errors.

Procedures

Choice of the periods

The first period (N) was chosen in 2015, seven days after the implementation of the CPOE in both departments. The second and third periods were selected at the same moments in 2014 (N − 1) and 2016 (N + 1), respectively.

Figure 1 shows the three 30-day periods over three consecutive years.

The populations' data

The number of inpatients and patient days for the three periods were extracted from the computerized patient records. The patients' lengths of stay were determined by calculating the quotient of the numbers of patient days by the number of patients.

Collection of the pharmaceutical interventions

The pharmacists performed a 3-level analysis of the medical prescriptions. In France, three levels of pharmaceutical analysis are defined by the French Society of Clinical Pharmacy (Société Française de Pharmacie Clinique or SFPC). Level 1 includes the choice and availability of drugs, doses, contraindications and drug interactions. Level 2 consists of level 1 and includes posology adaptations using the patients' biological results and records. Level 3 adds to the previous levels and includes the respect of the therapeutic objectives, drug monitoring and medication reconciliation [13]. For each identified problem, the pharmacist performs a pharmaceutical intervention to inform the prescriber of an error.

Before the CPOE, the pharmacists indicated all the PIs performed on the Act-IP site weekly. Act-IP is a French website developed by the SFPC that allows the collection and codification of PIs. The pharmacists record data about the patient (initials, age, gender and department) and the PIs (description, type of problem, type of solution and PI acceptance), which are then usable at local and national levels thanks to queries.

With the computerization, the PIs were recorded by the CPOE.

All the PIs were extracted and analysed using the Excel software.

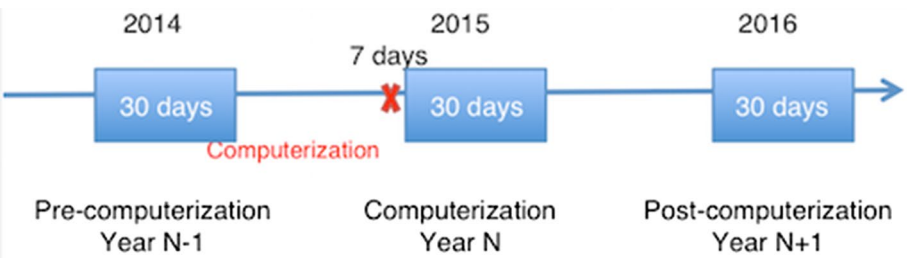

Fig. 1 The three study periods

Table 1 French society of clinical pharmacy's error classification

Types of errors
Non conformity to guidelines or contraindication
Untreated indication
Subtherapeutic dosage
Supratherapeutic dosage
Drug without indication
Drug interaction
Adverse effect
Improper administration instruction
Failure to receive drug
Drug monitoring
Computerization-related error

Table 2 Classification of computerization-related errors

Types of computerization related errors
Drug strength error
Unit error
Drug quantity error
Failure to stop treatment
Failure to renew treatment
Repeated prescription
Computer protocol not completed
Programming error
Computer protocol selection error

The PI profile

The PIs collected during the three periods were classified according to the different types of errors defined by the SFPC and listed in Table 1 [12].

The PIs were classified as computerization-related PIs (CPIs) when the errors resulted from the use of the CPOE and would not occur with handwritten prescriptions. The CPI sub-categories were based on the different identified errors and are presented in Table 2.

Rating of the clinical Impact

The CLinical Impact (CLI) reflects the severity of the prescribing errors. The PIs were submitted to a pharmacist and a physician and each one assessed the CLI. The CLI ratings were derived from a scale based on the classification used by V. Chedru and M. Juste, but the methodology used to process the data was very different [14]. The results from the two studies cannot be compared. Table 3 describes the CLI rating scale for the PIs used in this study.

Rating for PI acceptance

The outcome was monitored for each PI. The PI was rated as "accepted" when the prescriber took the comment into consideration or "not accepted". The PI was rated as "other" when there was no known outcome (patient discharged from the ward).

Outcome measures and statistical analysis

The main outcome measure was **the average number of PIs per 100 Patient Days** (mean, 95% Confidence Interval) as follows:

- Average number of total PIs (TPIs) per 100 patient days,
- Average number of computerization-related PIs (CPIs) per 100 patient days, and
- Average number of non-computerization-related PIs (NCPIs) per 100 patient days.

$$\frac{\text{number of PIs (TPIs, CPIs or NCPIs)} \times 100}{\text{number of patient days}}$$

Table 3 Clinical impact rating scale for pharmaceutical interventions

Clinical impact	Details
Harmful	The PI can lead to adverse outcomes for the patient
Non-existent	No consequences for the patient: • The PI represents an informative or financial target • The information available does not make it possible to determine the clinical impact of the PI
Weak	The PI optimises the patient's care (improvement of knowledge, adhesion, quality of life, and so on)
Significant	The PI increases treatment efficiency and/or patient safety and/or the patient's quality of life
Very significant	The PI prevents organic dysfunction, avoids intensive medical surveillance or irreversible sequelae
Vital	The intervention avoids a potentially fatal accident

The average numbers of PIs per 100 Patient Days from the three periods were compared two-by-two by using t-tests.

The secondary outcome measures were as follows:

- **The types of errors**

The errors were analysed descriptively.

- **The clinical impacts** (CLI) of the PIs
  - The CLIs were analysed descriptively and compared using Kruskal–Wallis tests (comparison of independent ordinal qualitative variables).
  - The interrater agreements between the pharmacist and physician were estimated using the kappa coefficient from the concordance tests (κ). The following standards for the strength of agreement defined by Landis and Koch were used: κ < 0 = poor, 0.00–0.20 = slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–1 = almost perfect [15].
- **PI acceptance** (accepted, not accepted, or other) **proportions**

The acceptance proportions of the three periods were compared two-by-two by using Chi Square tests.

Different criteria were followed over the three periods.

The statistical analyses were performed using the Excel and SPSS software (IBM society).

Results

The data from the populations

In total, 327 patients were hospitalized during the N − 1 period and 291 during both the N and N + 1 periods. The numbers of patient days (PDs) were 1001, 1016 and 1069, respectively, and the average lengths of stay were 3.1, 3.5 and 3.7 days, respectively.

The average number of PIs per 100 PDs

In total, 121 PIs were performed during the N − 1 period, 145 during the N period and 105 during the N + 1 period.

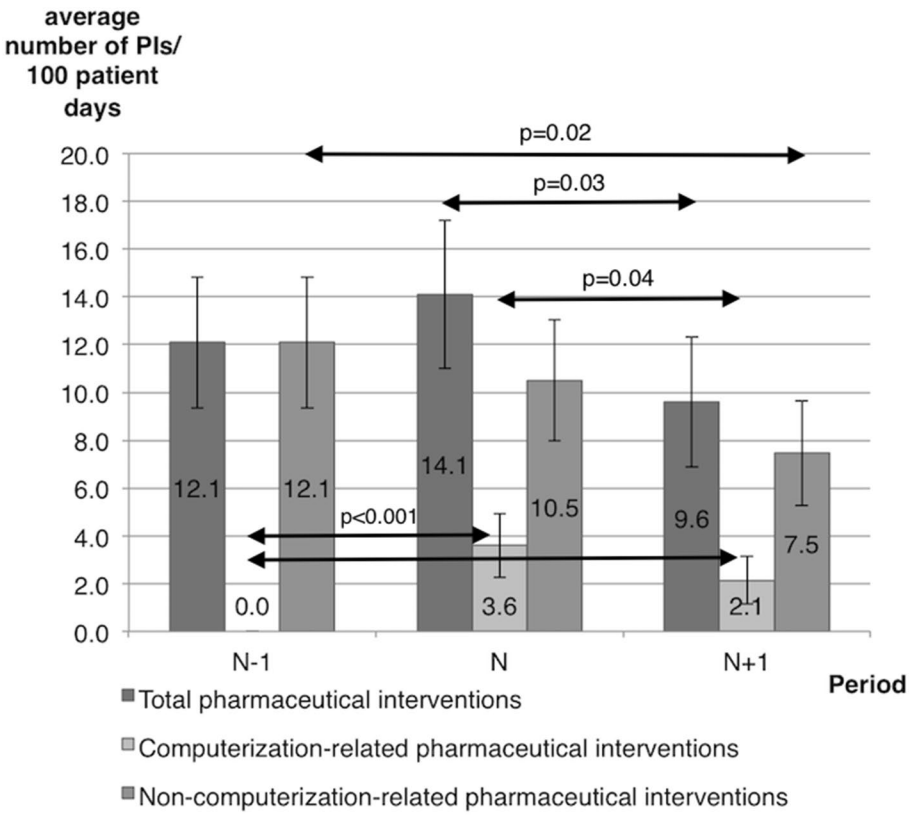

Fig. 2 The average number of pharmaceutical interventions per 100 patient days

Thirty-nine CPIs were highlighted during the N period and 22 CPIs during the N + 1 period.

Figure 2 shows the different average numbers for the PIs (TPIs, CPIs and NCPIs) for the 3 periods as follows:

- The average number of TPIs per 100 PDs significantly decreased from N (14.1) to N + 1 (9.6) ($p = 0.03$). There was no significant difference if we compare N − 1 with N then N + 1.
- The average number of CPIs per 100 PDs significantly increased in N and remained high in N + 1 ($p < 0.001$). It significantly decreased from N (3.6) to N + 1 (2.1) ($p = 0.04$).
- The average number of NCPIs per 100 PDs significantly decreased from N − 1 (12.1) to N + 1 (7.5) ($p = 0.02$). There was no significant difference if we compare N with N − 1 then N + 1.

Figure 2 illustrates the average number of PIs per 100 patient days with a 95% Confidence Interval using a histogram with the following results:

- N − 1: 12.1 (95%CI = 9.3–14.8) TPIs/100 PDs (TPIs = NCPIs)
- N: 14.1 (95%CI = 11.0–17.2) TPIs/100 PDs, 3.6 (95%CI = 2.3–4.9) CPIs/100 PDs, 10.5 (95%CI = 8.0–13.0) NCPIs/100 PDs
- N + 1: 9.6 (95%CI = 6.9–12.3)TPIs/100 PDs, 2.1 (95%CI = 1.1–3.1) CPIs/100 PDs, 7.5 (95%CI = 5.3–9.7) NCPIs/100 PDs

Table 4 Types of errors

Types of errors	N − 1 n = 121	N n = 145	N + 1 n = 105
Non conformity to guidelines or contraindication	14 (11.6%)	29 (20.0%)	18 (17.1%)
Untreated indication	29 (24.0%)	8 (5.5%)	8 (7.6%)
Subtherapeutic dosage	7 (5.8%)	7 (4.8%)	7 (6.7%)
Supratherapeutic dosage	19 (15.7%)	18 (12.4%)	10 (9.5%)
Drug without indication	12 (9.9%)	6 (4.1%)	11 (10.5%)
Drug interaction	10(8.3%)	10(6.9%)	4 (3.8%)
Adverse effect	0	6 (4.1%)	2 (1.9%)
Improper administration instructions	15 (12.4%)	21 (14.5%)	19 (18.1%)
Failure to receive drug	1 (0.8%)	1 (0.7%)	0
Drug monitoring	14 (11.6%)	0	4 (3.8%)
Computerization-related error	0	39 (26.9%)	22 (21.0%)
		n = 39	n = 22
Drug strength error		*6 (15.4%)*	*0*
Unit error		*12 (30.8%)*	*4 (18.2%)*
Drug quantity error		*0*	*3 (13.6%)*
Failure to stop treatment		*6 (15.4%)*	*2(9.1%)*
Failure to renew treatment		*1 (2.6%)*	*0*
Repeated prescription		*9 (23.1%)*	*12 (54.5%)*
Computer protocol not completed		*2 (5.1%)*	*0*

The types of PI problems

Table 4 shows the distribution of the PIs according to the SFPC error classification.

Before the CPOE implementation, the most common errors were "untreated indications" (24.0%), "supratherapeutic dosages" (15.7%) and "improper administration instructions" (12.4%).

After the CPOE implementation, the most common errors were "computerization-related errors" (26.9% and 21.0%), "non-conformity to guidelines or contraindications" (20.0% and 17.1%) and"improper administration instructions" (14.5% and 18.1%).

The computerization-related errors were classified into nine sub-categories. The most widespread errors were "unit errors" (30.8% and 18.2%) and "repeated prescriptions" (23.1% and 54.5%).

The clinical impact of the PIs

Table 5 reports the distribution of the PIs (TPIs, CPIs and NCPIs) according to the CLI assessed by a pharmacist and a physician.

The kappa coefficients for the both raters were moderate (kappa = 0.56, $p < 0.001$) for N − 1 and substantial (kappa = 0.68, $p < 0.001$/kappa = 0,77, $p < 0.001$) for N and N + 1. The global kappa coefficient was substantial (kappa = 0.66, $p < 0.001$).

The most usual CLI assigned by both raters was "significant" (from 45.5 to 55.2% for the TPIs). Only one PI was deemed as vital. No PI was rated as harmful.

As shown in Table 6, no significant difference in the CLI distribution was highlighted for the TPIs, CPIs or NCPIs over the three periods or between the CPIs and the NCPIs in N and N + 1.

The PI acceptance proportions

Figure 3 presents the acceptance proportions (accepted, not accepted and other PI proportions) per period. The accepted PI proportion increased significantly from N (46.9%) to N + 1 (60.0%) ($p = 0.04$). There was no significant difference for the not accepted PI proportion over the three periods. The other PI proportions significantly

Table 5 Clinical impacts of pharmaceutical interventions evaluated by a physician and a pharmacist

	N − 1		N						N + 1					
	TPIs = NCPIs		CPIs		NCPIs		TPIs		CPIs		NCPIs		TPIs	
Pharmacist														
Harmful	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Non-existent	9	7.4%	4	10.3%	12	11.3%	16	11.0%	1	4.5%	4	4.8%	5	4.8%
Weak	33	27.3%	9	23.1%	26	24.5%	35	24.1%	3	13.6%	23	27.7%	26	24.8%
Significant	66	54.5%	18	46.2%	54	50.9%	72	49.7%	12	54.5%	46	55.4%	58	55.2%
Very significant	13	10.7%	8	20.5%	14	13.2%	22	15.2%	6	27.3%	9	10.8%	15	14.3%
Vital	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	1.2%	1	1.0%
Physician														
Harmful	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Non-existent	15	12.4%	1	2.6%	12	11.3%	13	9.0%	0	0.0%	4	4.8%	4	3.8%
Weak	46	38.0%	14	35.9%	38	35.8%	52	35.9%	12	54.5%	26	31.3%	38	36.2%
Significant	55	45.5%	23	59.0%	48	45.3%	71	49.0%	3	13.6%	47	56.6%	50	47.6%
Very significant	5	4.1%	1	2.6%	8	7.5%	9	6.2%	7	31.8%	6	7.2%	13	12.4%
Vital	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Kappa coefficient	0.56 (moderate)		0.68 (substantial)						0.77 (substantial)					
Global Kappa coefficient	0.66 (substantial)													

Table 6 Comparison of the clinical impacts of pharmaceutical interventions with Kruskal–Wallis tests

	TPIs			NPCIs			CPIs		CPIs/NCPIs	
	N − 1	N	N + 1	N − 1	N	N + 1	N	N + 1	N	N + 1
Pharmacist										
p value	0.475			0.839			0.241		0.489	0.080
Physician										
p value	0.053			0.074			0.988		0.388	0.921

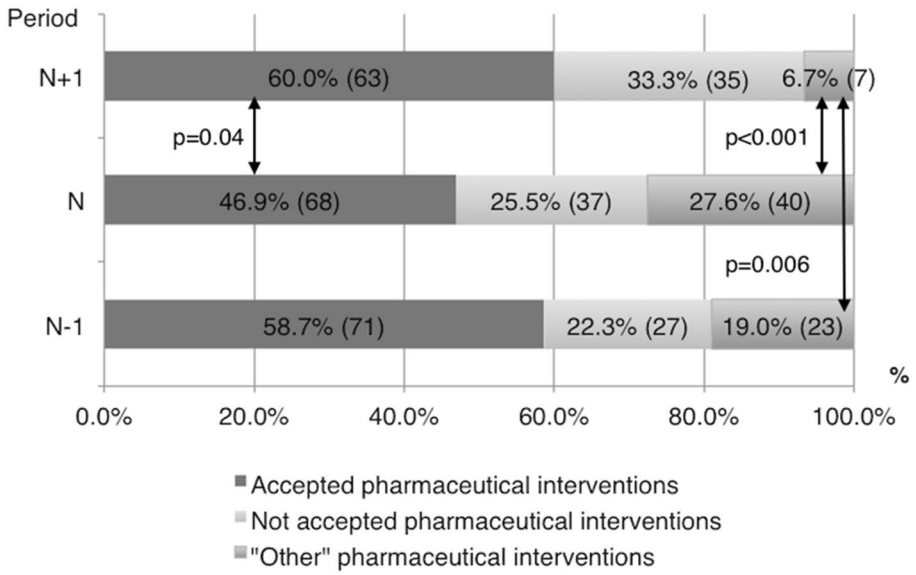

Fig. 3 Pharmaceutical intervention acceptance proportions by period

decreased from N − 1 (19.0%) to N + 1 (6.7%) and from N (27.6%) to N + 1 (6.7%) ($p < 0.01$).

Figure 3 illustrates the acceptance proportions (accepted, not accepted and other PI proportions) per period with a bar chart as follows:

- N − 1: accepted PI = 58.7%, not accepted PI = 22.3%, Other PI = 19.0%
- N: accepted PI = 46.9%, not accepted PI = 25.5%, Other PI = 27.6%
- N + 1: accepted PI = 60.0%, not accepted PI = 33.3%, Other PI = 6.7%

Discussion

For each outcome measure, we analysed the resulting evolution between the non-CPOE control period (N − 1) and the CPOE periods (N then N + 1). The comparison of the N and N + 1 periods estimated the influencing time on the results since computerization.

The averages

Unlike other studies, we determined the average number of PIs per 100 PDs instead of the number of validated prescriptions [16, 17]. This denominator is more stable because it is not influenced by multiple modifications to prescriptions. It also considers the patient lengths of stay to avoid a bias. Indeed, the longer a patient stays in a hospital, the more prescription errors that may be expected to occur.

Non-CPOE period versus CPOE periods

Computerization has led to a new risk with a significant occurrence of computerization-related errors (N: 3.6 CPIs per 100 PDs, N + 1: 2.1 CPIs per 100 PDs, $p < 0.001$). However, after a year of CPOE, computerization had a positive effect on the reduction in errors, which were not related to computerization itself. Indeed, the average number of NCPIs per 100 PDs significantly declined from 12.1 (N − 1) to 7.5 (N + 1) ($p = 0.02$). Additionally, the decrease in the NCPI average has probably been slightly underestimated by not accounting for some handwritten prescription errors (the lack of the patient's ID or the physician's signature, incomplete posology, etc.) during N − 1. These errors could not be considered as they are not represented in the SFPC classification used by the Act-IP site, and it was impossible to quantify their systematic loss during the computerized prescription.

The TPI average stability between the non-CPOE period and the two CPOE periods can be explained by the cumulative effect of the CPI appearance and the NCPI stagnancy then reduction.

The comparison of the two CPOE periods

The average number of TPIs and CPIs significantly decreased in N + 1. The decline of the CPI average suggests that computerization-related errors are temporary and decrease with time. This is probably the consequence of better CPOE use by the prescribers and of a software improvement by the editor. It would be interesting to repeat the evaluation with new prescribers and after software updates to examine the impacts of these changes.

The PI profile

During N − 1, the most common type of PI was "untreated indications" (n = 29, 24.0%). This kind of error was detected by medical reconciliation.

During N and N + 1, CPIs were the most common PIs at 26.9% and 21.0%, respectively. In their studies on computer tools, Charpiat et al. and Korb-Savoldelli et al. found that the proportions ranged from 5.9 to 35% and from 6.1 to 77%, respectively, according to the publications [3, 16]. The results of our study are included in these wide ranges. According to Lecointre et al., the high proportion of drug errors related to the computerization in their study is explained by the fact that all their prescribers were senior physicians. They made few prescribing errors, and those related to computerization were the most widespread [18].

In our study, we observed nine types of errors related to computerization. Unit errors (N: 30.8% and N + 1: 18.2%) and repeated prescriptions (N: 23.1% and N + 1: 54.5%) were the most frequently encountered. They were also the most likely found in the publications [18, 19]. Unit errors are often due to carelessness by the prescribers. Repetitions can be caused by poor legibility or by difficulties in seeing the entire computerized prescription.

The clinical impacts

The CLIs of PIs provide both an indication of the PI relevance and the severity of the prescribing error. The more important the PI CLI, the more potentially serious the prescribing error. Conversely, a harmful PI is an unjustified PI, which can lead to an unfavourable result for the patient.

The kappa coefficients obtained for each period and for the whole study indicated good concordance between the two raters (kappa ranging from 0.56 to 0.77).

The PI (TPI, CPI and NCPI) distributions according to their CLI were equivalent for the three periods (no significant differences). The CPOE did not influence the CLIs of the PIs, either right after its implementation or 1 year later.

The CLI of the CPI and NCPI distributions were also equivalent during the N and N + 1 periods. Therefore, the computerization-related errors were not more serious than other errors.

Acceptance proportions

Accepted and not accepted PI proportions remained stable from the non-CPOE period to both CPOE periods (no significant differences).

Only the PI proportion rated as "other" significantly decreased from 19% (N − 1) to 6.7% (N + 1) ($p = 0.006$). The "other" PIs match PIs whose future is unknown. Therefore, they could have been accepted or declined, which makes interpretation of the result difficult. However, the "other" PI decrease indicates that 1 year after its implementation, the CPOE allowed the pharmacists to perform a more reactive pharmaceutical analysis and therefore to communicate their PIs to the prescribers immediately after prescription.

Since computerization, the accepted PIs have significantly increased from 46.9% (N) to 60% (N + 1) and the "other" PIs have significantly decreased from 27.6% (N) to 6.7% (N + 1). The improvement in both of these proportions has confirmed that N was a transition period.

Our proportions of accepted PIs were 58.7% (N − 1), 49.6% (N) and 60% (N). This proportion is very variable in the scientific literature. It reaches 23% in Estallat's study and 99% in Leape's study [20, 21]. This proportion cannot be directly related to the relevance of the PIs because of other factors. A doctor can refuse a PI while it has been accepted by another one. The reluctance of doctors with regards to the arrival of the CPOE also distorts the results [22, 23]. The proportion of accepted PIs probably depends on the integration of pharmacists into the departments. In the first study, the PIs were completed remotely, while in the second, the pharmacists were present and regularly participated in the medical rounds. In our case, the pharmacists were well integrated into the departments, but did not systematically participate in the medical rounds.

Study limitations

We studied the prescribing errors across the PIs performed by the pharmacists. The PIs are reflections of prescribing errors, but they have a certain amount of subjectivity and may not be exhaustive. In fact, an error noted by a pharmacist may not be judged as such by the prescriber. The pharmacist can also miss out on some errors. Thus, the number of errors could have been under- or overestimated.

During the N − 1 period, some errors related to handwritten prescriptions were not considered. Thus, the NCPIs from the control period could have been underestimated.

Conclusion

During the period following CPOE implementation the prescription error profile changes and computerization-related errors become the most frequent. The average number of TPIs and NCPIs is similar to the handwritten prescription PIs.

One year after computerization, the number of classic errors decreases. The computerization-related errors will still be present, but progressively decrease, probably due to better training of the prescribers and improvements in the software ergonomics. The computerization-related errors seem not to be more serious than other errors.

The CPOE does not influence the CLIs of the PIs.

The accepted PIs significantly increased and the other PIs significantly decreased due to better communication between the pharmacists and prescribers. Indeed, CPOE use allows the pharmacists to perform pharmaceutical analysis immediately after prescription writing, improving the interactions with the physicians.

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Conflicts of interest None.

References

1. Bates DW, Teich JM, Lee J, Seger D, Kuperman GJ, Ma'Luf N, et al. The impact of computerized physician order entry on medication error prevention. J Am Med Inform Assoc. 1999;6:313–21.
2. Reckmann MH, Westbrook JI, Koh Y, Lo C, Day RO. Does computerized provider order entry reduce prescribing errors for hospital inpatients? a systematic review. J Am Med Inform Assoc. 2009;16:613–23.
3. Charpiat B, Bedouch P, Conort O, Rose FX, Juste M, Roubille R, et al. Opportunities for medication errors and pharmacist's interventions in the context of computerized prescription order entry: a review of data published by French hospital pharmacists. Ann Pharm Fr. 2012;70:62–74.
4. Charles K, Cannon M, Hall R, Coustasse A. Can utilizing a computerized provider order entry (CPOE) system prevent hospital medical errors and adverse drug events? Perspect Health Inf Manag. 2014;11:1b.
5. Nuckols TK, Smith-Spangler C, Morton SC, Asch SM, Patel VM, Anderson LJ, et al. The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors

in hospital settings: a systematic review and meta-analysis. Syst Rev. 2014;3:56.
6. Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, et al. Role of computerized physician order entry systems in facilitating medication errors. J Am Med Assoc. 2005;293:1197–203.
7. Ash JS, Sittig DF, Dykstra RH, Guappone K, Carpenter JD, Seshadri V. Categorizing the unintended sociotechnical consequences of computerized provider order entry. Int J Med Inf. 2007;76:S21–7.
8. Bouchand F, Thomas A, Zerhouni L, Dauphin A, Conort O. Pharmacists' interventions before and after prescription computerization in an internal medicine department. Presse Médicale. 2007;36:410–8.
9. Légifrance. Article L1121-1. Code de la Santé Publique.
10. Légifrance. Article L1121-2. Code de la Santé Publique.
11. Bright JM, Tenni PC. The clinical services documentation (CSD) system for documenting clinical pharmacists' services. Aust J Hosp Pharm. 2000;30:10–5.
12. Allenet B, Bedouch P, Rose F-X, Escofier L, Roubille R, Charpiat B, et al. Validation of an instrument for the documentation of clinical pharmacists' interventions. Pharm World Sci. 2006;28:181–8.
13. Juste M. Recommendation of good practice in clinical pharmacy. Analysis of prescription and levels of pharmaceutical analysis. Le Pharm Hosp Clin. 2012;47:293–5.
14. Chedru V, Juste M. Medical assessment of the pharmaceutical intervention clinical impact. Je Pharm Clin. 1997;16:254–8.
15. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:165.
16. Korb-Savoldelli V, Boussadi A, Durieux P, Sabatier B. Prevalence of computerized physician order entry systems-related medication prescription errors: a systematic review. Int J Med Inf. 2018;111:112–22.
17. Shulman R, Singer M, Goldstone J, Bellingan G. Medication errors: a prospective cohort study of hand-written and computerised physician order entry in the intensive care unit. Crit Care. 2005;9:R516–21.
18. Lecointre R, Dakessian MP, Mezzour A. Retrospective study of computerized medication errors in a surgical clinic. Le Pharmacien hospitalier et clinicien. Paris: Elsevier Masson SAS; 2014. p. 1–12.
19. Vialle V, Tiphaine T, Poirier Y, Raingeard E, Feldman D, Freville JC. To know, understand and combat medication errors related to computerized physician order entry. Ann Pharm Fr. 2011;69:165–76.
20. Estellat C, Clombet I, Vautier S, Huault-Quentel J, Durieux P, Sabatier B. Impact of pharmacy validation in a computerized physician order entry context. Int J Qual Health Care. 2007;19:317–25.
21. Leape LL, Cullen DJ, Dempsey Clapp M, Burdick E, Demonaco H, Erickson JI, et al. Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. JAMA. 1999;281:267–70.
22. Khanna R, Yen T. Computerized physician order entry: promise, perils, and experience. Neurohospitalist. 2014;4:26–33.
23. Gellert GA, Ramirez R, Webster SL. Toward the elimination of paper orders. Appl Clin Inform. 2016;7:33–42.