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Computerized physician order entry of injectable antineoplastic drugs: An epidemiologic study of prescribing medication errors

V. Nerich[a,b], S. Limat[a,b,*], M. Demarchi[c], C. Borg[c,d], P.S. Rohrlich[d,e], E. Deconinck[f], V. Westeel[g], C. Villanueva[c], M.C. Woronoff-Lemsi[a,b], X. Pivot[c,d]

[a] Department of Pharmacy, Jean Minjoz University Teaching Hospital, Besançon, France
[b] EA4267–UFR-133, School of Medicine and Pharmacy, Besançon, France
[c] Department of Medical Oncology, Jean Minjoz University Teaching Hospital, Besançon, France
[d] INSERM U645 EA-2284 IFR-133, Besançon, France
[e] Department of Hematology-Pediatrics, Jean Minjoz University Teaching Hospital, Besançon, France
[f] Department of Hematology, Jean Minjoz University Teaching Hospital, Besançon, France
[g] Department of Pneumology, Jean Minjoz University Teaching Hospital, Besançon, France

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ABSTRACT

Purpose In the context of CPOE of standardized antineoplastic drugs, the objectives of the present study were to determine the incidence of prescribing medication errors (PME) and to analyse PME related to antineoplastic treatment in university teaching hospitals. *Methods*: All consecutive prescribing medication orders over 1 year were analysed prospectively. Potential clinical impact was quoted according to the Hatoum scale and risk factors identified with a logistic-regression model. *Results*: A total of 14,854 prescriptions were analysed. The PME incidence was estimated at 1.5% [1.3–1.7], *i.e.* 15 errors per 1000 prescribing medication orders, with a significant or very significant potential clinical impact in 62.9% of cases. Potentially death-threatening events were avoided in 3.7% of cases. Overall, PME incidence related to significant, very significant or vital potential clinical impact was estimated to be 1.0% [0.8–1.2], *i.e.* 10 errors per 1000 prescribing medication orders. The most common type of error was related to antineoplastic drug dosage (61.0%): inadequate adaptation (43.1%), not taking alarms into account (16.1%), incorrect weight (0.9%), incorrect unit (0.9%). More than 20% of PME are medication errors directly linked to the prescribing medication order (choice of antineoplastic treatment, double-prescribing medication order, forgotten or not validated by a resident or senior physician). Occasional users of the CPOE system and resident physicians were identified as main PME risk factors. *Conclusion*: An epidemiologic survey of PME in the context of the use of a partial CPOE has allowed to determine the incidence and epidemiology of PME as well as the potential clinical impact they represent. Two risk factors have emerged that can be considered from an organization and software points of view. Better pharmacist's analysis of prescribing medication order within the CPOE system could possibly minimize duplication of antineoplasic drugs and the vital clinical impact associated with overdosage.

* *Corresponding author at*: Pôle Pharmaceutique, Centre Hospitalier Universitaire Jean Minjoz, Boulevard Fleming, 25030 Besancon Cedex, France. Tel.: +33 381668641; fax: +33 381668489.
E-mail address: slimat@chu-besancon.fr (S. Limat).
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1. Introduction

Medication errors occur commonly in hospitals, increasing both morbidity and mortality. The economic impact of these errors may be considerable [1–6]. Thus, the occurrence of an adverse drug event has been associated with increased length of hospitalisation from 1.9 to 4.6 days and an additional overcost of 1788 to 4629 euros [5]. Many medication errors happen at the prescription stage. Their prevention is a public health priority, which could have a considerable impact on the incidence of preventable adverse drug events [7,8].

In the near future, prescribing will be performed through the use of Computerized Physician Order Entry (CPOE) systems. Organizing and securing the CPOE are recognized priorities in health care institutions [7,8]. CPOE of antineoplastic drugs has improved the quality of physician order entry and has limited the risk of prescribing medication errors (PME) [9–20]. A 55–80% decrease has been reported in the literature. Commonly, standardization of protocols by computerized systems aims to secure practitioner prescription. However, one of the main possible errors is linked to the prescription phase. The complexity of anticancer treatment could increase medication and prescription errors. Moreover, anticancer treatment related toxicity has a major impact on clinical efficacy.

In the context of CPOE of standardized antineoplastic drugs, the objectives of the present study were to determine the incidence of PME and to analyse PME related to antineoplastic treatment in university teaching hospitals.

2. Materials and methods

2.1. Setting

Besançon University Hospital is the referent regional center in cancerology for the Franche-Comté region in eastern France. Drug order entry is fully computerized for injectable chemotherapy prescriptions, from the medical office to the centralized pharmaceutical unit in charge of antineoplastic drug preparation. BPC® software (acronym for Bonnes Pratiques de Chimiothérapie, meaning Good Use of Chemotherapy) was implemented for routine use in 2003. In our hospital, only all antineoplastic treatments are prescribed through this system. This software tool development has required the competence of a multidisciplinary staff. The project was supported by grants and public health resources. BPC® includes a specific thesaurus per tumour for all available antineoplastic treatments. This thesaurus resulted from a regional consensus meeting involving every physician authorized to treat cancer patients.

The therapeutic strategy decision and initiation systematically come from a multidisciplinary committee. A senior physician begins the antineoplastic treatment, then may or may not choose to delegate the next prescribing medication order to resident physicians.

Computerized prescribing medication order, including doses and administration procedure (route, infusion timing and duration, fluid) for each antineoplastic drug, is carried out and then validated by a referent physician. The computerized antineoplastic treatments could include a single antineoplastic drug or a combination, given on one day or on several days. All calculations (drug dose according to weight, body surface area or the Calvert/Chatelut formula) are automatized at each step by the CPOE system. Each prescribing medication order is secured by multiple alarms: dose variation between two courses, exceeding maximal and cumulative doses, unexpected values of weight or size or body surface area, improbable interval between two prescriptions... Physicians, like pharmacists, have full access to each patient's past treatment history.

The prescribing medication order is transferred from the physician's office to the centralized pharmaceutical unit by the computerized network and linked to a drug card-index (preparation procedures, concentration of active solution, incompatibilities). Before preparation, each prescribing medication order is reviewed by a pharmacist, according to a standardized process. The pharmacist checks and validates all the following items:

- items related to patient characteristics: sex, age, size, weight, body surface area, serum creatinine;
- items related to prescribing medication order: accordance between disease stage and antineoplastic treatment selection, choice of prescribed schedule, modified and unmodified with regard to the previous cycle, expected interval between two cycles;
- items related to the dose: change between two cycles, exceeding the maximum or cumulative dose, renewal loading dose (yes or no), no renewal of previous modification; a dose may be modified up to a 2.5% limit to facilitate the preparation;
- items related to treatment setting: day ward or hospitalisation.

2.2. Period study

All consecutive medication orders prescribed from 1 February 2007 to 31 January 2008 were analysed prospectively in real-time by a resident or pharmacist.

2.3. Prescribing medication error

A prescribing medication error (PME) was defined as any abnormality occurring in the prescription process and discovered by pharmacists. Then, prescribing physicians (resident or senior) were contacted to check and to confirm their prescriptions. In case of error, the computerized prescription medical order was corrected. Inter-observer reliability was not evaluated [21].

2.4. Potential clinical impact

The potential clinical impact of each medication error was scored using a validated scale at four levels proposed by Hatoum et al. [22] This scale assesses the potential clinical impact of medication errors avoided by the pharmacist's intervention: (1) no potential impact; (2) significant potential impact (increase of effectiveness and/or security and/or qual-

ity of life); (3) very significant potential impact (preventing organ dysfunction and/or an intensive medical surveillance and/or an irreversible sequela); (4) vital potential impact (avoiding a potentially fatal accident).

PME were retrospectively quoted by an independent referent panel of physicians (six medical oncologists, three pneumologists and three hematologists, one of whom has a dual competency in hematology and pediatrics).

2.5. *Risk factors*

Several potential risk factors for PME occurrence were searched for. They include: patient characteristics (age, sex), prescription characteristics (first cycle *versus* following cycles), number of injectable antineoplastic drugs per prescription (single antineoplastic drug *versus* multiple), cycle duration (one day *versus* several days), prescribing medication order integrated into a clinical trial or not, *status* of the physician (resident physician *versus* senior physician, occasional user of the CPOE system (*i.e.* <1 prescribing medication order per day) *versus* regular user of the CPOE system (*i.e.* ≥1 prescribing medication order per day)) and treatment setting (day ward *versus* hospitalisation).

Table 1 – Patient characteristics and number of prescribing medication orders, physicians and pharmacists.

Patient characteristics	
Mean age ± Sd	58.8 ± 16.4
Sex, number (%)	
Female	7814 (52.6)
Male	7040 (47.4)
Number of prescribing medication orders (%), according to	
Cancer	
Breast cancer	3765 (25.3)
Colorectal cancer	2598 (17.5)
Lung cancer	1777 (12.0)
Hematology	2622 (17.6)
Pediatric cancer	571 (3.8)
Other	3521 (23.7)
Duration of cycle	
One day	13,345 (89.8)
Several days	1509 (10.2)
Treatment setting	
Day ward	12,188 (82.1)
Hospitalisation	2666 (17.9)
Number of	
Prescribing physicians	65
Senior physicians	36
Residents physicians	29
Pharmacists	3

2.6. *Statistical analysis*

The unit of analysis was the prescribing medication order (*i.e.* one prescription including either a single or multiple injectable antineoplastic drugs). Continuous variables were described by mean ± standard deviation (Sd) and qualitative variables by the size and the percent rate. Qualitative variables were compared by the Fisher exact test or the chi-square test.

The analysis of PME risk factors was performed in a three steps approach. Firstly, the association of potential PME risk factors with observed PME (yes/no) was examined by univariate analysis. Quantitative and qualitative variables were transformed, whenever possible, into dichotomic variables, using different successive cut-off points. Secondly, all variables with a p-value <0.15 in univariate analysis were entered in a stepwise logistic-regression model. In a first overall analysis, all types of error were considered. Thirdly, only PME with significant, very significant and vital potential clinical impact were studied. The results of multivariate analyses are presented with adjusted odds ratio, 95% confidence intervals (95% CI) and p-value.

All tests were two-tailed and significant at an alpha threshold of 5% (p). Statistical analysis was performed with SAS® software version 9.1.

Table 2 – Types of prescribing medication error.

Setting of pharmacist's intervention	Confirmed prescribing medication errors, *n* (%)				
	Overall	According to potential clinical impact			
		No	Significant	Very significant	Vital
Dose prescribed	133 (61.0)	22 (30.2)	80 (80.0)	29 (78.4)	2 (25.0)
Inaccurate adaptation	94 (43.1)	13 (17.8)	55 (55.0)	25 (67.6)	1 (12.5)
Alarms not taken into account	35 (16.1)	8 (11.0)	25 (25.0)	2 (5.4)	–
Incorrect weight	2 (0.9)	1 (1.4)	–	1 (2.7)	–
Incorrect unit	2 (0.9)	0 (0.0)	–	1 (2.7)	1 (12.5)
Prescribing medication order	45 (20.6)	15 (20.5)	17 (17.0)	7 (18.9)	6 (75.0)
Choice of antineoplastic treatment	23 (10.6)	6 (8.2)	13 (13.0)	4 (10.8)	–
Double	16 (7.3)	6 (8.2)	2 (2.0)	2 (5.4)	6 (75.0)
Forgotten or not validated by a senior or resident physician	6 (2.7)	3 (4.1)	2 (2.0)	1 (2.7)	–
Management	34 (15.6)	32 (43.8)	1 (1.0)	1 (2.7)	–
Inaccurate date of antineoplastic treatment	27 (12.4)	25 (34.2)	1 (1.0)	1 (2.7)	–
Inaccurate treatment setting identification	7 (3.2)	7 (9.6)	–	–	–
Patient characteristics: identity	3 (1.4)	3 (4.1)	–	–	–
Inadequate interval between two cycles	3 (1.4)	1 (1.4)	2 (2.0)	–	–
Overall	218 (100.0)	73 (100.0)	100 (100.0)	37 (100.0)	8 (100.0)

Table 3 – Examples of potential prescribing medication error prevented by pharmacists.

Type of prescribing medication error	Example
Dose prescribed – inaccurate adaptation	Bevacizumab 10 mg/kg (560 mg) instead of 15 mg/kg (840 mg) Cyclophosphamide at a dose of 70 mg (7%) instead of 626 mg (70%) Cetuximab at a dose of 472.5 mg (100%) instead of 311.9 mg (66%) Cetuximab 80% plus folfox 80% instead of cetuximab 80% plus irinotecan 80% plus fluorouracil diffuser 80% Bortezomib on days 4, 8, 11 at 100% (2.0 mg) instead of 59% (1.2 mg)
Dose prescribed – alarm not taken into account	Vincristine >2 mg (2.6 mg) Body surface area >2 m^2 (2.2): Folfiri regimen
Dose prescribed – incorrect weight	74 kg instead of 64 kg carboplatin 5AUC on day 1 plus etoposide 100 mg/m^2 on days 1 through 3
Dose prescribed – incorrect unit	Methotrexate at a dose of 3 mg instead of 3000 mg
PMO – choice of antineoplastic treatment	Bortezomib instead of "bortezomib trial"
PMO – double	2 Methotrexate 10 mg/m^2 (16.2 mg) instead of 1 methotrexate 10 mg/m^2 (16.2 mg) 2 Docetaxel 35 mg/m^2 (63.7 mg) instead of 1 docetaxel 35 mg/m^2 (63.7 mg)
PMO – forgotten by a resident or senior physician	Bevacizumab 15 mg/kg instead of bevacizumab 15 mg/kg plus paclitaxel 80 mg/m^2 (123.2 mg)
Inaccurate date of antineoplastic treatment	Paclitaxel 80 mg/m^2 (128,8 mg) February 2nd instead of February 1st Trastuzumab 6 mg/kg (396 mg) August 1st instead of August 2nd Gemcitabine on day 1 and oxaliplatin on day 2 instead of both on day 1
Inaccurate treatment setting identification	Department of Medical Oncology level −1 instead of level −2

Abbreviation: PMO = prescribing medication order.

3. Results

During the 1-year study period, 14,854 consecutive computerized prescribing medication orders were analysed, corresponding to 34,566 preparations of antineoplastic drugs for 2056 patients. The mean number of antineoplastic drugs per prescription was 2.34 ± 2.53. Antineoplastic drugs were administered on a single day and in day ward, respectively, in 89.8% and 82.1% of cases. Patient characteristics are summarized in Table 1.

3.1. *Incidence and potential clinical impact of prescribing medication errors*

Among the 14,854 prescriptions studied, a pharmacist intervened in 459 cases (3.1% [2.8–3.4]): 241 prescribing medication orders were confirmed and 218 included only one medication error (PME) (Table 2). Thus, the prescribing medication error incidence was estimated at 1.5% [1.3–1.7], *i.e.* 15 errors per 1000 prescribing medication orders.

According to Hatoum et al.'s 4-level scale, 100 (45.9%) and 37 (17.0%) of 218 identified PME were considered to have either a significant potential clinical impact or a very significant potential clinical impact, respectively. A potential fatal event was avoided by pharmacists in 8 cases (3.7%). Overall, PME incidence related to significant, very significant or vital potential clinical impact ($n = 145$) was estimated to be 1.0% [0.8–1.2], *i.e.* 10 errors per 1000 prescribing medication orders.

3.2. *Epidemiology of prescribing medication errors*

PME types are summarized in Table 2, with some examples in Table 3. The least often identified PME are related to patient

Table 4 – Description of prescribing medication error with potential vital clinical impact.

Type of PME	Antineoplastic treatment	Number of patients
Dose prescribed – incorrect unit	Asparaginase 33,800 KUI instead of 33.8 KUI	1
Double-PMO	Doxorubicine 25 mg/m^2 plus bleomycine 10 mg/m^2 plus vinblastine 6 mg/m^2 plus dacarbazine 375 mg/m^2 on day 1	3
Double-PMO	Ifosfamide 3 g/m^2 on days 1 through 3	1
Double-PMO	Gemcitabine 1000 mg/m^2 plus cisplatine 100 mg/m^2 on day 1	1
Double-PMO	Docetaxel 75 mg/m^2 plus cisplatine 75 mg/m^2 plus 5-fluorouracile 3750 mg/m^2 on day 1 instead of docetaxel 75 mg/m^2 plus 5-fluorouracile 3750 mg/m^2 on day 1	1
Double-PMO	Docetaxel 35 mg/m^2 (63.7 mg)	1

Abbreviation: PME = prescribing medication error.

Table 5 – Univariate analysis of prescribing medication error risk factors.

n (%)	Prescription medication order	PME	*p*-Value
Patient			
Age (years)			0.87
≤18	644 (4.3)	10 (1.6)	
>18	14,210 (95.7)	208 (1.5)	
Sex			0.89
Female	7,814 (52.6)	116 (1.5)	
Male	7,040 (47.4)	102 (1.5)	
Prescription medication order			
First cycle			0.02
Yes	3,418 (23.0)	36 (1.1)	
No	11,436 (77.0)	182 (1.6)	
>1 antineoplastic drugs per regimen			$<10^{-5}$
Yes	6,653 (44.8)	133 (2.0)	
No	8,201 (55.2)	85 (1.0)	
>2 antineoplastic drugs per regimen			$<10^{-7}$
Yes	4,275 (28.8)	101 (2.4)	
No	10,579 (71.2)	117 (1.1)	
Duration of cycle			0.65
One day	13,345 (89.8)	194 (1.4)	
Several days	1,509 (10.2)	24 (1.6)	
Clinical trial			0.73
Yes	1,414 (9.5)	22 (1.6)	
No	13,440 (90.5)	196 (1.5)	
Physician status			
Prescribing physician			$<10^{-4}$
Resident physician	5,159 (34.7)	105 (2.0)	
Senior physician	9,695 (65.3)	113 (1.2)	
User of the CPOE system			$<10^{-3}$
Occasional	238 (1.6)	12 (5.0)	
Regular	14,616 (98.4)	206 (1.4)	
Treatment setting			0.06
Day ward	12,188 (82.1)	168 (1.4)	
Hopitalization	2,666 (17.9)	50 (1.9)	

Abbreviation: PME = prescribing medication error.

Table 6 – Multivariate analysis of prescribing medication error risk factors.

Risk factors	Odds ratio	95% Confidence interval	*p*-Value
218 PME occurrences			
>2 antineoplastic drugs per prescription	2.28	1.74–3.00	$<10^{-4}$
Occasional user of the CPOE system	3.85	2.08–7.14	$<10^{-4}$
Resident physician	1.53	1.16–2.00	10^{-3}
First cycle of prescribing medication order	0.64	0.44–0.92	0.02
145 PME occurrences with a significant, very significant or vital potential clinical impact			
>2 antineoplastic drugs per prescription	2.28	1.63–3.18	$<10^{-4}$
Occasional user of the CPOE system	4.76	2.44–9.09	$<10^{-4}$
Resident physician	1.73	1.24–2.42	$<10^{-2}$

Abbreviation: PME = prescribing medication error.

identity (1.4%) and to an inadequate interval between two cycles (1.4%).

An inaccurate date of antineoplastic treatment or treatment setting identification (hospitalisation instead of day ward, or inversely), without potential clinical impact for the patient, was identified in more than 15% of PME.

Although more than 20% of PME are medication errors directly linked to the prescribing medication order (choice of antineoplastic treatment, double-prescribing medication order, forgotten or not validated by a senior or resident physician), the most common type of detected PME was related to antineoplastic drug dose (61.0% of cases):

- inaccurate adaptation in 43.1% of cases: no renewed adaptation (35.8%, for example with: cetuximab, fluorouracil) despite alarm, no adaptation (1.8%), no loading dose (4.1%, example:trastuzumab), loading dose (0.5%, example: trastuzumab), renewed loading dose (0.9%, example: trastuzumab);
- not taking alarms into account in 16.1% of cases: exceeding themaximum doses (example: vincristine >2 mg), body surface area >2 m^2,

- other errors in 1.8% of cases: incorrect weight (0.9%), incorrect unit (0.9%, example: KUI instead of UI).

Heights PME with vital potential clinical impact are summarized in Table 4. They are mainly related to double-PMO.

3.3. *Prescribing medication error risk factors*

The results of univariate analysis are summarized in Table 5.

As significant risk factors for 218 PME occurrences, the multivariate analysis pointed out: >2 antineoplastic drugs per protocol, occasional user of the CPOE system and resident physician (Table 6). Interestingly, the first cycle is a significant protective factor for PME occurrence.

Similar results were observed in a second analysis restricted to 145 PME with a significant, very significant or vital potential clinical impact (Table 6).

4. Discussion and conclusion

The prevention of medication errors is recognized as a priority for public health. The CPOE of antineoplastic drugs, or other drugs, has reduced the incidence of PME, but could be further improved and secured in an active quality policy [9–20]. In our university teaching hospital, we attempt to reduce their incidence by combining CPOE and standardization of protocols by computerized systems. In this context, it is interesting to assess the incidence of PME and to identify risk factors of their occurrence.

Despite this organization, the incidence of PME was estimated at 1.5% of prescribing medications orders or at 1.0% when taking into account only significant, very significant and vital potential clinical impact errors. This value is low when compared to the incidence reported in published studies, varying from 2.7% to 12.3% [9,12–14,16–18,23,24]. It is debatable whether or not the present study results may be compared with those obtained in the literature; study designs are different (handwritten *versus* computerized prescriptions, basic computerized system), and their settings are different (intensive care unit, medicine unit, internal medicine, centralized antineoplastic preparation unit). However, our study seems showed that the CPOE system is effective.

The results of the present study need to be viewed within its limited context. The study was conducted in only one university hospital. The CPOE system limited to antineoplastic treatment could account for a lower incidence of PME than in a complete CPOE system. Only PME identified by a pharmacist were taken into account, thus excluding: (1) the PME not identified by a pharmacist and which can therefore never be identified *a posteriori* by a pharmacist or prescribing physician, and which could have a potentially significant impact on clinical efficacy; and (2) supplementary therapies (antiemetics, corticosteroids...) and hydratation; and (3) errors occurring during the preparation process in the centralized pharmaceutical unit in charge of antineoplastic drug preparation. Because of these limitations PME incidence may be underestimated.

The epidemiology of PME related to antineoplastic treatment is completely different from PME identified in the literature [14,16,18,19,25]. Standardization of protocols by computerized systems secures practitioner prescription. No PME are related to dose calculation or administration procedure [14,16,18,19,25].

In our study, nearly 25% of PME are easily preventable: due to an inaccurate date of antineoplastic treatment or treatment setting identification, a double- or not validated prescribing medication order. As a result, patients have to wait longer. Although there is no significant clinical impact, the organization and planning within a given ward could be disrupted. More than 10% of PME are related to the choice of antineoplastic treatment and may also cause errors which might potentially have an impact on clinical efficacy. A quality policy could substantially reduce these errors by incorporating the medical consultation report and/or multidisciplinary committee report into the CPOE system. However, the most common type of PME is related to the dose prescribed, that is to say 0.9%: inaccurate adaptation of doses and not taking alarms into account. Adaptation errors could be reduced by securing the duplication of the previous prescribing medication order. Routinely, alarms are mandatory rather than optimal but could be insufficient or unsuitable. Interestingly, despite many alarms helping prescribing physicians, more than 50% of prescribing medication errors are caused by disregard for this security measure. It is essential to increase vigilance and adapt alarms to the needs of prescribing physicians in order to reduce these errors and vital potential clinical impact.

This is the first study which has assessed the risk of prescribing medication errors in the context of optimal computerized and standardized prescription in cancerology. It is noteworthy that two preventable risk factors are identified: occasional user of the CPOE system (OR = 3.85, 95% CI = 2.08–7.14) and resident physician (OR = 1.53, 95% CI = 1.16–2.00). Fijn et al. assessed the risk of prescribing errors in the context of handwritten prescriptions [25]. They showed that prescribing medication error occurred more frequently with an assistant clinician than with clinician staff (OR = 1.57, 95% CI = 1.15–2.14) [25]. By focusing efforts on these two risk factors, the risk of PME might further be reduced. Efforts should include better standardization of schedules, system simplification and specific training of prescribing resident physicians.

In conclusion, an epidemiologic survey of PME in the context of the use of a partial CPOE has allowed to determine the incidence and epidemiology of PME as well as the potential clinical impact they represent. Two risk factors have emerged that can be considered from an organization and software points of view. Better pharmacist's analysis of prescribing medication order within the CPOE system could possibly minimize duplication of antineoplasic drugs and the vital clinical impact associated with overdosage.

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Summary points

What was known before the study?

- The prevention of medication errors is recognized as a priority for public health. The CPOE of antineoplastic drugs, or other drugs, has reduced the incidence of PME, but could be further improved and securized in an active quality policy.
- In our university teaching hospital, combining CPOE and standardization of protocols by computerized systems is aimed at reducing their incidence.

What this study has added to the knowledge base?

- Despite this organization, a residual risk of PME was estimated at 15 errors per 1000 prescribing medication orders.
- The epidemiology of PME is completely different from PME identified in the literature. The most common type of PME is related to the dose prescribed: wrong adaptation of doses and not taking alarms into account. The errors of adaptation could be reduced by securizing the duplication of the previous prescribing medication order. It is essential to increase vigilance and adapt alarms to the needs of prescribing physicians in order to reduce these errors.
- Our study was the first study which has assessed the risk of prescribing medication error in the context of optimal computerized and standardized prescription in cancerology. It is noteworthy that two preventable risk factors are identified: occasional user of BPC® software and resident. By focusing efforts on these two risk factors, the risk of PME might further be reduced. Efforts should include better standardization of schedules, system simplification and specific training of prescribing physicians.
- Conclusion: Computerizing and standardizing antineoplastic drug prescribing medication orders seem to be efficient. Nevertheless, a residual risk of prescribing medication errors was identified and explained, in part, by risk factors. Improving BPC® software and raising prescribing physicians' awareness should improve the quality and security of the CPOE.

REFERENCES

[1] R.A. Brennan, L.L. Leape, N.M. Laird, Incidence of adverse events and negligence in hospitalized patients, N. Engl. J. Med. 324 (1991) 370–376.

[2] L.L. Leape, T.A. Brennan, N.M. Laird, The nature of adverse events in hospitalized patients, N. Engl. J. Med. 324 (1991) 377–384.

[3] J. Lazarou, B.H. Pomeranz, P.N. Corey, Incidence of adverse drug reactions in hospitalized patients: a meta-analysis of prospective studies, JAMA 279 (1998) 1200–1205.

[4] D.W. Bates, N. Spell, D.L. Cullen, The costs of adverse drug events in hospitalized patients, JAMA 227 (1997) 307–311.

[5] D.C. Classen, Pestotnik Sl, R.S. Evans, J.F. Lloyd, J.P. Burke, Adverse drug events in hospitalized patients: excess length of stay, extra-costs, and attributable mortality, JAMA 277 (4) (1997) 301–306.

[6] B. Dean, M. Schachter, C. Vincent, N. Barber, Prescribing errors in hospitals inpatients: their incidence and clinical significance, Qual. Saf. Health Care 11 (2002) 340–344.

[7] Conference of World Health Organization, 24 September 2007, http://www.who.int/en/ (accessed 2 March 2009).

[8] Mission Inter-ministérielle de Lutte Contre Le Cancer, Plan Cancer, 2003–2007, http://www.sante.gouv.fr/htm/dossiers/cancer/ (accessed 2 March 2009).

[9] J.M. Teich, P.R. Merchia, J.L. Schmiz, G.J. Kuperman, C. Spurr, Bates DW, Effects of computerized physician order entry on prescribing practices, Arch. Intern. Med. 160 (2000) 2741–2747.

[10] D.W. Bates, Using information technology to reduce rates of medication errors in hospitals, BMJ 320 (7237) (2000) 788–791.

[11] R. Kaushal, K. Shojania, D. Bates, Effects of computerized physician order entry and clinical decision support systems on medication safety. A systematic review, Arch. Intern. Med. 163 (2003) 1409–1416.

[12] E. Oren, E.R. Shaffer, B.J. Guglielmo, Impact of emerging technologies on medication errors and adverse drug events, Am. J. Health Syst. Pharm. 60 (2003) 1447–1458.

[13] R.J. Blendon, C.M. DesRoches, M. Brodie, Views of practicing physicians and the public on medical error, N. Engl. J. Med. 347 (2003) 1933–1967.

[14] A. Bobb, K. Gleason, M. Husch, J. Feinglass, P. Yarnold, G. Noskin, The epidemiology of prescribing errors: the potential impact of computerized prescriber order entry, Arch. Intern. Med. (2004) 785–792.

[15] R. Koppel, J.P. Metlay, A. Cohen, B. Abaluck, A.R. Localio, S.E. Kimmel, et al., Role of computerized physician order entry systems in facilitating medication errors, JAMA 293 (2005) 1197–1203.

[16] R. Shulman, M. Singer, J. Goldstone, G. Bellingan, Medication errors: a prospective cohort study of hand-written and computerized physician order entry in the intensive care unit, Crit. Care 9 (2005) 516–521.

[17] A. Oliven, I. Michalake, D. Zalman, E. Dorman, D. Yeshurun, M. Odeh, Prevention of prescription errors by computerized, on-line surveillance of drug order entry, Int. J. Med. Inform. 74 (2005) 377–386.

[18] M.J. Huertas Fernandez, J.M. Baena-Canada, M.J. Martinez Bautista, E. Arriola Arellano, M.V. Garcia Palacios, Impact of computerized chemotherapy prescriptions on the prevention of medication errors, Clin. Transl. Oncol. 8 (11) (2006) 821–825.

[19] V.M. Bradley, C.L. Steltenkamp, K.B. Hite, Evaluation of reported medication errors before and after implementation of computerized practitioner order entry, J. Healthc. Inform. Manage. 20 (4) (2006) 46–53.

[20] G.R. Kim, A.R. Chen, R.J. Arceci, S.H. Mitchell, K.M. Kokoszka, D. Daniel, et al., Error reduction in pediatric chemotherapy: computerized order entry and failure modes and effects analysis, Arch. Pediatr. Adolesc. Med. 160 (2006) 495–498.

[21] D. Sackett, R. Haynes, G. Guyatt, Clinical Epidemiology: A Basic Science for Clinical Medicine, Little, Brown, Boston, MA, 1991.

[22] H.T. Hatoum, R.A. Hutchinson, L.R. Elliott, D.L. Kendzierski, Physician's review of significant interventions by clinical pharmacist in inpatient care, Drug Intell. Clin. Pharm. 22 (1988) 980–982.

[23] K.E. Walsh, K. Dodd, K. Seetharaman, D.W. Roblin, L.J. Herrinton, Von Worley, et al., Medication errors among adults and children with cancer in the outpatient setting, J. Clin. Oncol. 27 (6) (2009) 891–896.

[24] T. Gandhi, S. Bartel, L.N. Shulman, D. Verrier, E. Burdick, A. Cleary, et al., Medication safety in the ambulatory chemotherapy setting, Cancer 104 (11) (2005) 2289–2291.

[25] R. Fijn, P. Van den Bemt, M. Chow, C.J. De Blaey, L. De Jong-Van den Berg, J. Brouwers, Hospital prescribing errors: epidemiological assessment of risk, Br. J. Clin. Pharmacol. 53 (2001) 326–331.