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Impact of an intervention to reduce prescribing errors in a pediatric intensive care unit

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Abstract *Purpose:* To identify and reduce medication prescribing errors in a pediatric intensive care unit (PICU) by means of an educational program designed to improve medical prescriptions. *Methods:* Before–after interventional study in a tertiary-level PICU. Handwritten prescriptions were prospectively collected: 2,228 during period 1 and 1,791 during period 2. In both periods elements of good prescribing practice including error indicators and quality indicators were studied. The interventional program included four measures: standardization of prescription sources, pocket tables with dosing guidelines, an updated prescription protocol, and an educational program on correct prescribing. *Results:* The prescribing error (PE) rate decreased from 34.2 to 21.7 % after the intervention. Lack of administration route was considered separately for its high prevalence, 30 and 20.8 % of prescriptions, respectively. The most frequent error was presence of some illegible element (59 %). Legibility was the element of prescription experiencing the greatest reduction in error rate, from 4.1 % of prescriptions with one or more illegible elements in period 1 to 0.2 % in period 2. Tenfold overdosage decreased from two cases in period 1 to one case in period 2. The attending physician and on-call physician were associated with more PEs in both periods. The number of prescriptions with two or more errors decreased from 3.1 to 0.7 %. Errors reaching the patient were scarce, 14 (0.63 %) in period 1 and 6 (0.34 %) in period 2, without adverse events. *Conclusions:* Implementation of an educational program for physicians may significantly reduce the prescribing error rate in a PICU.

Keywords Medication errors · Prescribing error · Intensive care unit · Pediatrics

Introduction

Drug prescription and administration errors are an important source of iatrogenic morbidity and mortality in hospitalized patients. A systematic review of adverse events in hospitalized patients described a rate of 9.2 %, with 15.1 % as a consequence of medication errors [1]. While 7.4 % of adverse events were lethal, 43.5 % of them were considered preventable. A Spanish survey on hospitalization-associated adverse events (ENEAS 2005) [2] found that medication error-related adverse events affected up to 4 % of hospitalized patients. Adverse drug events are classified as preventable when resulting from medication errors or nonpreventable when resulting from adverse drug reactions [3]. Medication errors include, in increasing severity, those that do not reach the patient, those that reach the patient without harm, and those that harm the patient [4].

In pediatric patients the most common medication errors are those of prescription and, among these, errors of dosage and frequency of administration [5, 6]. The variations in weight and pharmacokinetics of pediatric patients make them more prone to prescribing errors (PEs) [7–10]. There are few data about the incidence of PEs in neonatal [11, 12] and pediatric intensive care units (PICU) [13–15], although most studies suggest they may be quite frequent. The first study that separately analyzed PEs in pediatric patients described 0.49 PEs per 100 medication orders [16]. The first study on PEs in a PICU by Potts et al. [15] found a PE rate of 30.1 %, much higher than described in other pediatric studies. Subsequent studies in pediatric and neonatal ICUs [11–14] reported similar PE rates, ranging from 11 to 39 % [12, 14].

The objective of the present study is to analyze the prevalence of drug PEs and their clinical impact in a PICU. The interventional part of the study included standardization of the sources of prescription, pocket tables with dosing guidelines, the development of an updated prescription protocol, and the implementation of an educational program for physicians on drug errors and correct prescribing strategies.

Materials and methods

A before–after design without control group was used. Four-month preinterventional data collection (July through October 2008, period 1) was followed by 12 months of site-specific error reduction interventions. After that, 4-month postinterventional data collection was completed (November 2009 through February 2010, period 2). The study was performed in a tertiary, academic, 16-bed PICU that attends neonates and children up to 14 years of age with any type of medical pathology as well as postoperative patients with cardiac surgery and liver transplant. The medical staff includes four attending physicians and at least two residents, while the on-call team (from 3 p.m. to 8 a.m. and weekends) consists of one attending physician and one resident.

At our unit, drug prescriptions are written by hand and rewritten at least every 24 h, even when there is no change in medication, regimen or dose. All medication orders were included except fluids, nutrition (enteral or parenteral), blood products, as well as potassium, calcium, and sodium bicarbonate given as intravenous bolus. Elements of good prescribing practice (GPP) were compiled from the study of Dean et al. [17] about PEs and the prevention of medication errors in the pediatric inpatient setting recommendations of the American Academy of Pediatrics [18]. Each drug prescription was evaluated for name, dosage, units, route, and administration interval. The study of the elements of GPP included not only PEs but also quality indicators. The lack of quality indicators is not properly a PE, but it may favor their appearance. PEs were classified as dose error (any dose that was more than 10 % above or below the correct dose based on patient weight according to the PICU's protocols), legibility error, omission error (incomplete prescription), and wrong elements error (incorrect drug, dilution, units, or route). The prescribing quality indicators included use of the amount of active agent, generic names, unabbreviated units, and specification of the dose per kilogram used for dose calculations. The severity level of errors was graded following the taxonomy proposed by the group of Ruiz-Jarabo [19] (Table 1).

The sample size was calculated based on pediatric PE rates published in the literature, which range from 11 to 39.5 % of all prescriptions [11–15]. In order to detect a 5 % reduction in errors, assuming an 80 % power and a

Table 1 Index for categorizing medication errors

Error type	Category	Definition
No error	Category A	Circumstances or events that have the capacity to cause error
Error, no harm[a]	Category B	An error occurred, but the error did not reach the patient[b]
	Category C	An error occurred that reached the patient but did not cause patient harm
	Category D	An error occurred that reached the patient and required monitoring[c] to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm
Error, harm	Category E	An error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention[d]
	Category F	An error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization
	Category G	An error occurred that may have contributed to or resulted in permanent patient harm
	Category H	An error occurred that required intervention necessary to sustain life[e]
Error, death	Category I	An error occurred that may have contributed to or resulted in the patient's death

[a] Harm: impairment of the physical, emotional or psychological function or structure of the body and/or pain resulting therefrom

[b] An "error of omission" does reach the patient

[c] Monitoring: to observe or record relevant physiological or psychological signs

[d] Intervention: may include change in therapy or active medical/surgical treatment

[e] Intervention necessary to sustain life: includes cardiovascular and respiratory support [e.g., cardiopulmonary resuscitation (CPR), defibrillation, intubation, etc.]

significance level of 5 %, the minimum sample required in each period was 1,565 prescriptions. The sampling was stratified by the day of the week.

The main outcome variable was prevalence of medication errors during each phase. The PE rate was calculated as the percentage of errors relative to total orders. The percent change in error rate was determined as follows [20]: [(%errors postintervention − %errors at baseline)/%errors at baseline] × 100. Data were summarized according to a method of descriptive analysis. A Fisher exact test was used for preintervention and postintervention data comparison, and Cox regression was used to estimate the adjusted prevalence ratios and to identify potential confounding or interaction factors. All statistical work was conducted in the environment of SPSS software (version 15; SPSS, Inc.), and p value <0.05 was considered significant.

All prescriptions were reviewed and classified by a single PICU specialist (A.M.A.) who did not perform any prescriptions on the days selected for data collection. The rest of the PICU staff (physicians and nurses) knew about the study but did not know the days selected for data collection. The review of the prescriptions was carried out while they were still valid before they were written again the next day. Whenever an error that could harm the patient was detected, it was corrected and discussed with the attending physician. In cases where an error reached the patient, that patient was followed for 2 weeks to detect potential harm and to grade the severity of the error. The project was approved by the research ethics committee of the Hospital Universitario 12 de Octubre de Madrid.

Results

A total of 4,019 prescriptions were reviewed during the two periods of the study. The prescribing physician was a resident in 76.3 % of cases and an attending staff physician in 23.7 %. The moment of prescription was during the daily rounds in 54.9 %, while the rest were made by the on-call physician. The prescriptions were made for a total of 151 medications, although 50 % belonged to the 12 most frequently used drugs. The most frequent categories were anti-infectious (14 %), diuretics (13.6 %), anesthetics (13.1 %), vasoactive drugs (10 %), analgesics (9.3 %), and gastric acid inhibitors (6.8 %). Characteristics of the prescriptions during both periods are presented in Table 2. Based on the analysis of the data from period 1 an interventional program consisting of the following measures was designed: (1) standardization of the sources of prescription of all drugs used in the PICU based on a common pediatric handbook [21], (2) implementation of a dosing guideline for the most frequent drugs at the PICU (pocket table), (3) carrying out of an updated protocol on correct prescription, and (4) incorporation of an educational program on drug errors and correct prescription strategies.

The different types of deviation from GPP in both periods of study are summarized in Table 3. Although the preinterventional rate of GPP deviations was 88.6 %, only 34.2 % were PEs while 69 % were prescriptions of poor quality. Overall, the intervention rendered a 12.3 % reduction in the number of prescriptions with deviation from GPP. The largest reduction was observed in the rate of PEs (36.5 %), with only 8.4 % improvement in the quality of the prescriptions. Although there was a significant reduction in the number of errors, when stratified for type of error only the group of legibility errors and omission errors had a statistically significant reduction, of 95.1 and 87.5 %, respectively. Dose errors and wrong element errors diminished by 28.6 and 46.1 %, respectively. The most frequent error for both periods was "administration route not specified," appearing in 30 and 20.8 % of prescriptions, respectively. When the route of administration was not specified, most of the time these were prescriptions of continuous infusions failing to specify the intravenous route of administration (e.g., dopamine). PEs other than

Table 2 Prescription characteristics for both study periods

Prescription characteristics	Period 1	Period 2	p-Value
Prescriptions reviewed	2,228	1,791	
Days of revision	22	21	
Patients reviewed	52	67	
Prescriptions/patient-day	11.98 ± 0.25	11.78 ± 0.27	0.60[1]
Days of revision/patient	2 (1, 4)	2 (1, 3)	
Weight (kg)	3.6 (2.65, 14)	5.5 (3.5, 11)	<0.001[1]
Age (months)	3.3 (0.87, 22.03)	5.17 (1.5, 19.1)	0.067[1]
Prescriptions			
On weekends	560 (25.1 %)	416 (23.2 %)	0.16[2]
On-call	1,030 (46.2 %)	782 (43.7 %)	0.1[2]
Residents	1,668 (74.9 %)	1,400 (78.2 %)	0.01[1]

Values are given as mean ± standard deviation (SD), median with quartiles, or number with percentages of total prescriptions for each period in parenthesis

[1] p Mann–Whitney test, [2]p Fisher exact test

Table 3 Prescriptions with deviations from good prescribing practice (GPP) in both study periods

Deviations from GPP	Period 1 ($n = 2,228$)	Period 2 ($n = 1,791$)	Percent change	Prevalence ratio (95 % CI)	p-Value
Any deviation from GPP	1,975 (88.6 %)	1,392 (77.7 %)	−12.3	0.88 (0.85–0.9)	<0.001
Any deviation from GPP (except "administration route not specified")	1,594 (71.5 %)	1,141 (63.7 %)	−10.9	0.89 (0.85–0.93)	<0.001
One or more elements of poor quality	1,537 (69 %)	1,133 (63.2 %)	−8.4	0.92 (0.88–0.96)	<0.001
One or more prescribing errors	761 (34.2 %)	388 (21.7 %)	−36.5	0.63 (0.57–0.7)	<0.001
One or more prescribing errors (except "administration route not specified")	154 (7 %)	25 (1.4 %)	−80	0.2 (0.13–0.31)	<0.001
More than one prescribing error	69 (3.1 %)	13 (0.7 %)	−77.4	0.23 (0.13–0.42)	<0.001
One or more wrong elements	28 (1.3 %)	13 (0.7 %)	−46.1	0.58 (0.3–1.11)	0.114
Dose error	16 (0.7 %)	8 (0.5 %)	−28.6	0.62 (0.27–1.45)	0.308
Omission error (except "administration route not specified")	17 (0.8 %)	2 (0.1 %)	−87.5	0.15 (0.03–0.63)	0.002
Illegible prescriptions	91 (4.1 %)	4 (0.2 %)	−95.1	0.05 (0.02–0.15)	<0.001

p Fisher exact test

Table 4 Prescriptions with errors categorized by prescribing physician in both study periods

	Resident physician, n (%)	Attending physician, n (%)	Prevalence ratio (95 % CI)	p-Value
Period 1	541 (32.43)	220 (39.29)	1.21 (1.07–1.37)	0.003
Period 2	254 (18.14)	134 (34.27)	1.89 (1.58–2.25)	<0.001

n prescriptions with an error, p Fisher exact test

"administration route not specified" were due to the presence of some illegible element in 59 % of cases. In period 1, "illegible units" was the second error in frequency, affecting 3 % of prescriptions, a percentage that dropped to 0.2 % following the introduction of the improvement measures. Incorrectly calculated doses were detected in 16 prescriptions during period 1 and 8 prescriptions during period 2, resulting in overdosage in 81 and 63 %, respectively. Tenfold overdosage occurred in three cases, two during period 1 and one during period 2, although the latter was detected by the nurse and did not reach the patient. The number of erroneous elements in a single prescription fell from 3.1 % of prescriptions with two or more incorrect elements in period 1 to 0.7 % in period 2 (prevalence ratio 0.23, 95 % confidence interval 0.13–0.42), with a percent change of 77.4 %. Medications with the highest rate of PEs (excluding those with administration route not specified) were diazepam (21.1 %), dopamine (11.9 %), and milrinone (13.7 %) during period 1 and morphine chloride (42.8 %), fibrinogen (16.6 %), and fentanyl (5.3 %) during period 2.

When analyzing the factors that were associated with a higher percentage of PEs, it was seen that in both periods prescriptions made by the attending physician and on-call physician were associated with significantly more errors than those made by a resident (Table 4) and during the daily rounds, respectively. Prescriptions made by the on-call team during both study periods showed a significantly higher PE rate, 40.8 and 26.6 %, respectively ($p < 0.05$). Nonetheless, there was also a significant reduction of PEs among attending physicians and on-call physicians during period 2. The variables that significantly influenced the efficacy of the intervention in reducing PEs during period 2 were the prescribing physician (Table 4) and the patient's weight. The efficacy of the intervention was higher among residents than among attending physicians. The intervention also achieved a greater reduction in PEs among patients with lower body weight.

Among the elements of poor quality, absence of dose per kilogram of weight was noted for its frequency (55 %), followed by the use of the tradename instead of the generic name (32 %) (Table 5). Errors that reached the patient were scarce (Table 6), 14 (0.63 %) in period 1 and 6 cases (0.34 %) after applying improvement measures, overdosage being the most frequent in both periods. No major adverse effects (category of severity ≥E) related to PEs were reported.

The incidence of PEs showed a significant increasing trend during period 1. During period 2 the incidence showed a significant declining trend until the third month of study and was then balanced for the rest of the period.

Discussion

The error rate of 34.2 % found in our study is in accordance with the literature, although the different criteria for

Table 5 Elements of poor quality in both study periods

	Period 1 (n = 2,228) (%)	Period 2 (n = 1,791) (%)	Prevalence ratio (95 % CI)	p-Value
Dose per kilogram, missing	55.5	55.7	1 (0.95–1.06)	0.476
Trade name	32.3	23.5	0.73 (0.66–0.81)	<0.001
Unit, liquid or pill form	7.7	7.5	0.96 (0.78–1.2)	0.765
Abbreviation	4.2	1.4	0.33 (0.21–0.51)	<0.001
Dose per kilogram, wrong	1.1	0.9	0.88 (0.47–1.64)	0.753

p Fisher exact test

Table 6 Prescriptions with errors that reached the patient during both study periods

	n (%)	Error types	Category[a]
Period 1 (n = 14)			
Amikacin	1 (7.1)	Overdosage (maximum dose)	C
Clonazepam	1 (7.1)	Tenfold overdosage	D
Dexchlorpheniramine	5 (35.7)	Overdosage	C
Spironolactone	2 (14.2)	Overdosage	C
Phenytoin	1 (7.1)	Incorrect dilution	C
Isoniazid	1 (7.1)	Lower dose	C
Meropenem	1 (7.1)	Lower dose	C
Milrinone	1 (7.1)	Overdosage	C
Ranitidine	1 (7.1)	Tenfold overdosage	D
Period 2 (n = 6)			
Cephazolin	1 (16.6)	Overdosage	C
Fentanyl	1 (16.6)	Lower dose	C
Metamizol	1 (16.6)	Overdosage	C
Paracetamol	2 (33.3)	One overdosage, one lower dose	C
Vecuronio	1 (16.6)	Lower dose	C

[a] See index for categories of medication errors in Table 1

PE, considering only the most relevant elements of the prescription, could explain the differences in reported PE rates. Pallas et al. [12] consider "incorrect prescriptions," including both errors and elements of poor quality, which would account for the 39 % PE rate, the highest reported so far. To simplify comparisons with other studies we decided to analyze the deviations from GPP globally and then stratify them into PEs and poor quality of prescription.

The preinterventional study of PEs and poor-quality elements of prescription allowed the intervention to be focused on the most frequent deviations from GPP where there was greater margin for improvement. The most frequent error in both periods was "administration route not specified," being in most cases intravenous infusion. This reflects acquired habits at the unit, where it is understood that there is only one possible route for intravenous infusions. Although this must still be regarded as an error, we decided to consider it separately for its high incidence in order to avoid bias.

Although there was an overall significant reduction in the number of PEs, when analyzing separately the different PE types only omission errors and legibility errors showed a significant reduction. Dose errors and wrong element errors diminished postinterventionally without reaching significance. Other authors such as Potts et al. [15] also failed to see a significant improvement of these PE types. Since most measures during the intervention were aimed at completeness and legibility of prescriptions, this may account for the greater improvement of these errors. Electronic prescriptions have been shown to reduce the PE rate [12, 15, 22, 23], but at the time of study an electronic order system was not available in our unit. Based on our study results, electronic prescriptions are now being introduced, although, to prevent verbal orders, handwritten prescriptions are still being used during emergency situations when immediate access to a computer is not possible. These prescriptions are later transcribed onto the electronic system. All PEs that reached the patient (except one) during both periods were dose errors. Because of their potential harmfulness, reduction of dose errors may require not only training of the prescribing physicians but also specific education of nurses to detect them [24] and perhaps collaboration with a pharmacist at the unit, as already done at other PICUs [13, 15].

The intervention achieved not only a reduction in the absolute number of erroneous prescriptions but also a reduction in the number of erroneous elements on a single prescription. This is relevant because, according to the "Swiss cheese" model, there are usually multiple barriers to filter errors, and a hole in one barrier can be blocked by

the next [25]. Therefore, the risk of a medication error increases when there are multiple failures or holes in the system barriers, resulting in accidents when they align. Thus, if there are several errors on a single prescription, the next barrier of the system (i.e., another physician or a nurse) will have greater difficulty in detecting it and the chance that it will reach the patient increases. Although small, the percentage of errors that reached the patient was relevant because of the type of drugs involved, including vasoactive drugs, anesthetics, and muscle-relaxing agents. Moreover, when the dose per kilogram is not specified, the system barriers cannot act properly. This element of poor quality was the most frequent in both periods, and its frequency remained almost unchanged by the improvement measures. Although not itself a PE, it constitutes an important element of the prescription that allows recalculation of the dose and detection of errors before they reach the patient. Thus, improvement measures should place more emphasis on this aspect, probably giving it greater relevance in the training system on prescription.

Contrary to what might have been expected, residents presented a lower number of PEs. Residents also showed greater compliance with improvement measures, which stresses the importance of acquiring good prescribing habits early during the physician's education. The greater PE rate among the on-call team can be explained by the fact that the same workload is managed by only two physicians. However, it should be considered that a reduced workflow during the night shift may also predispose to errors of all kinds, including PEs.

Median patient weight was significantly higher during period 2, but not median patient age. Since the efficacy of the intervention was less with higher patient weight, the number of PEs would have been even lower during period 2 if there had not been a higher median weight.

Among the possible limitations of the study, the method of a chart review to detect PEs can induce the "Hawthorne effect" whereby subjects improve or modify an aspect of their behavior being measured in response to the fact that they are being studied and not in response to any particular experimental manipulation [26]. The study design implied that the medical prescribers knew that the data collection was being conducted, but to minimize this effect they did not know the date or the time of the prescription review. However, regarding the temporal trend of deviations from GPP during both periods, it becomes evident that this effect does not significantly slant results. During period 1 of the study, the number of deviations from GPP not only did not decline with time, but increased.

Conclusions

Prescribing errors are a common problem in PICUs, although few of them reach the patient. The introduction of a simple preventive educational program for physicians may significantly reduce the elements of poor quality and the PE rate.

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