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ORIGINAL ARTICLE

Incident reports versus direct observation to identify medication errors and risk factors in hospitalised newborns

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Abstract

Newborns are often exposed to medication errors in hospitals. Identification and understanding the causes and risk factors associated with medication errors will help to improve the effectiveness of medication. We sought to compare voluntary incident reports and direct observation in the identification of medication errors. We also identified corresponding risk factors in order to establish measures to prevent medication errors. Medication errors identified by a clinical pharmacist and those recorded in our incident reporting system by caregivers were analysed. Main outcomes were rates, type and severity of medication error, and other variables related to medication errors. Ultimately, 383 medication errors were identified by the clinical pharmacist, and two medication errors were declared by caregivers. Prescription errors accounted for 38.4%, preparation errors for 16.2%, and administration errors for 45.4%. The two variables significantly related to the occurrence of medication errors were gestational age < 32.0 weeks ($p = 0.04$) and the number of drugs prescribed ($p < 0.01$).

Conclusion: Caregivers underreported the true rate of medication errors. Most medication errors were caused by inattention and could have been limited by simplifying the medication process. Risk of medication errors is increased in newborns < 32.0 weeks and increases with the number of drugs prescribed to each patient.

What is Known:
- *Newborns in hospitals are particularly susceptible to medication errors.*
- *Identification and understanding the reasons for medication errors should help us to establish preventive measures to reduce the occurrence of such errors.*

What is New:
- *Direct observation of the medication process, though time consuming, is essential to accurately assess the frequency of medication errors, which are underreported by caregivers.*
- *Most medication errors are caused by inattention and could be limited by simplifying the medication process.*
- *The risk of medication errors was significantly increased in very preterm newborns (< 32 weeks) and when the number of prescription per patient increased.*

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Keywords Medication errors · Newborn · Risk factors · Neonatal intensive care unit · Patient safety · Quality improvement

Abbreviations
NICU Neonatal intensive care unit

Introduction

Since the publication in 1999 of *To Err Is Human*, medical errors and their management have become a worldwide priority for public health and patient safety. Drug use is the leading cause of iatrogenic incidents in medical practice [2, 11, 17, 26, 28]. In hospitals, drug process, which includes prescription, retranscription, preparation, and administration, involves various caregivers throughout the chain. Medication errors may happen at any point in the process [4, 12, 30]; sometimes, such errors have serious effects on patient health. Newborns, in particular, are at high risk for medication errors. Although the rate of medication errors is not higher in the neonatal population than in adults, the rate of adverse drug events is three times higher [14].

Many methods for the identification of medication errors have been recommended; these include direct observation, incident reports (including voluntary reports), use of triggers, and chart review [10]. These methods tend to underestimate the true rate of medication error [22]. The method used to estimate the rate of medication error in hospitals or healthcare facilities typically depends on the resources available. Previous studies comparing such methods have assessed efficacy, accuracy, and cost [3, 10, 21, 25]. These studies suggest that incident reports identify the fewest medication errors but are effective in capturing the incidence of severe drug-related issues. Direct observation is most effective for detecting medication errors but is also more costly than voluntary submission of incident reports [10, 21].

In many care facilities, incident report systems are used for risk management and improving the quality of healthcare. Incident reports allow for analysis of medication use in order to prevent the occurrence of similar errors in the future. Since 2006, medication errors occurring in the Clinic of Neonatology at our hospital have been voluntarily and anonymously reported by nurses and physicians in a specific incident reporting system, ProGREI. This study was performed with two primary objectives. First, we aimed to compare two methods for detection of medication errors, voluntary incident reports and direct observation, in order to determine the rate of detection of medication errors and the types of errors made most frequently. Secondly, we sought to analyse medication errors highlighted by direct observation in order to identify risk factors that contribute to the occurrence of such errors. This information should facilitate the implementation of interventions to reduce the occurrence of medication errors in the neonatal intensive care unit (NICU).

Patients and methods

Setting

This study was carried out in the 12-bed tertiary level neonatology NICU of the Clinic of Neonatology, Lausanne University Hospital, Switzerland. The staff of clinicians includes 13 senior and 12 junior physicians. Every 6 months, approximately 50% of these 25 physicians complete their clinical rotations and move to other paediatric clinics. Two teams, each comprising one senior and one junior physician, conduct medical rounds each day from 9:00 to 12:00. In our NICU, physicians' orders are currently handwritten on a medical order sheet. The teams re-evaluate patients' conditions and decide on therapeutic strategies. Drug therapies and written prescriptions entered in the medical order sheet are reviewed daily.

In Europe and the USA, many hospital pharmacies provide centralised intravenous additive services, but our hospital does not. Except for parenteral nutrition, cytotoxics, and specific oral liquids and capsules which are formulated by the hospital pharmacy, drugs are prepared and administered by nurses. All medication errors occurring in the Clinic of Neonatology are voluntarily and anonymously reported by nurses and physicians and recorded in a non-punitive incident reporting system, ProGREI. Each medication error recorded is reviewed by a multidisciplinary team, the NICU ProGREI team, which comprises a senior physician, a senior nurse, and a clinical pharmacist. This team analyses the medication errors reported in order to identify the nature and severity of each incident and to determine which course of action should be taken to improve safety. The severity of each medication error was determined consensually according to our Clinic of Neonatology's classification (Table 1).

The present study included patients hospitalised in the NICU for at least 24 h who were prescribed ≥ 3 drugs. Patients were included before medical rounds, every morning from Monday through Friday. Because of the observational design of the study and in order to witness the maximum number of preparations and drug administrations, each patient was included only for a single 24-h period. Medication errors related to blood products (except albumin), oxygen, and nitric oxide were beyond the scope of the present study. The study protocol was approved by the Ethics Committee for Human Research of Canton Vaud (local protocol number: 201/12).

Table 1 Classification and definition of medication error severity, according to our Clinic of Neonatology

Level	Definitions
Minor	No lesion. No requirement for therapy or special monitoring
Moderate	Requirement for routine specific therapy or monitoring
Serious	Death or life-threatening (requiring resuscitation in an intensive care unit)

Data collection and analysis

We analysed all medication errors that occurred during prescription, preparation, or administration in the NICU and were voluntarily reported in ProGREI by nurses or physicians from June to September 2010 and from August to November 2012. These errors were compared with medication errors detected prospectively through direct observation by a clinical pharmacist. The 2-year gap between observation periods reflects a change in the medical order sheet used in our NICU. The old medical order sheet, a simple white sheet, was replaced with a new, more structured medical order sheet that supplies preformatted information. Medication errors were analysed over the entire period of the study (8 months).

The clinical pharmacist was present during the medical rounds to witness drug prescriptions as well as drug preparation and administration by nurses. Observational periods extended from 8:00 to 17:00, Monday through Friday. The clinical pharmacist's observations were recorded in a computerised database (FileMaker Pro 11.0v3; FileMaker Inc., Santa Clara, CA), which was developed specifically for the study. A medication error was defined as any error in the medication process that affected the prescription, preparation, or administration of medication. A medication error may or may not have resulted in patient harm but was always considered preventable [9].

Direct observation and voluntary incident reporting were compared in terms of the number of medication errors identified, type of error, and severity of the error.

For each drug prescription, the accuracy of the indication, commercial name or active ingredient, dose, dosage, frequency, unit dose, route of administration, and rate of administration were verified in relation to the patient's clinical condition and textbooks used in our NICU, including the *Swiss Drug Information*, *Neofax*, *Manual of Neonatal Care* [6], *BNF for Children 2011–2012*, and *Uptodate Online.* The accuracy of drug preparation in relation to the prescription was assessed according to the following criteria: active ingredient, diluent, dosage, dose, dosage-form, and drug expiration date. Adherence to aseptic technique according to our NICU procedure was also recorded. The accuracy of drug administration in relation to the prescription was assessed according to the following criteria: omission, drug (active ingredient), patient, dose, dosage-form, technique of administration (including route of administration and rate of administration), drug expiration date, and time of administration.

Medication errors recorded in ProGREI as well as those observed prospectively by the clinical pharmacist were then analysed by the same clinical pharmacist and classified according to staging (prescription, preparation, or administration). Medication error type and severity were classified based on consensus by the NICU ProGREI team according to previously published standards [23], with slight modifications. Medication error severity was determined according to our Clinic of Neonatology's classification (Table 1). Each medication error detected by the clinical pharmacist was intercepted and corrected before it has reached the patient, and was immediately signalled to the responsible caregiver. In our study, each medication error detected by the clinical pharmacist was counted as wrong in the results.

The entire study, including its objective, design, and duration, was described to the medical and nursing staff prior to its inception. All physicians and nurses had previously received an information letter detailing the study and its purpose.

Statistical analysis

Medication error rates were calculated as percentages of the number of drug orders prescribed, prepared, or administered. Several multivariate Poisson regressions were performed to identify risk factors for medication errors. Different outcomes were considered: number of prescription errors, number of preparation errors, number of administration errors, total number of medication errors, and number of errors of moderate severity. For each outcome, the following explicative variables were included in the analysis: year (2010, 2012), birth weight (≥ 2500 g, 1500–2499 g, 1000–1499 g, < 1000 g), gestational age (> 37.0 weeks, 32.0–37.0 weeks, < 32.0 weeks), disease severity (determined according to the *Swiss Society of Neonatology* classification, which considers nursing resources required per patient), mode of ventilation (room air, continuous positive airway pressure (CPAP) or mechanical ventilation), and number of drugs prescribed per patient. For categorical explicative variables (except for number of drugs), the estimated incidence rate of medication error in each category was compared to the reference category. For the number of drugs prescribed, variation in incidence rate was computed for a one-unit increase. The χ^2 test was used to confirm differences in the frequency of errors of moderate severity among administration, prescription, and preparation errors.

Results

Types of medication errors

One hundred sixty-four patients were included in the study, accounting for a total of 164 patient-days. Mean gestational

age was 33.4 weeks (absolute range, 25.2–41.4). Mean birth weight was 2025 g (absolute range, 472–4520). Mean number of drug prescriptions per patient was 6.5 (absolute range, 2–18). Patient characteristics are presented in Table 2. During the two phases of the study, the clinical pharmacist recorded observations on 1062 prescriptions, 882 preparations, and 886 drug administrations.

A total of 383 medication errors were identified by the clinical pharmacist, accounting for 2.3 errors each patient-day. Among the 164 patients admitted, 139 (84.8%) were affected by one or more medication errors; 96 (58.5%) of these 139 newborns were affected by more than one medication error. Among the 383 medication errors identified, severity was classified as minor for 324 (84.6%) and as moderate for 59 (15.4%). No serious error was observed. Among the errors observed, 147 (38.4%) occurred during prescription, 62 (16.2%) occurred during preparation, and 174 (45.4%) occurred during administration. Dose omission ($n = 40$; 27.2%), improper dose ($n = 31$; 21.1%), and incorrect drug name ($n = 28$; 19.0%) were the most common types of errors during the prescription stage. Incorrect volume of diluent ($n = 19$; 30.6%), lack of adherence to aseptic requirements ($n = 18$; 29.0%), and incorrect preparation technique ($n = 17$; 27.4%) were the most common errors during the preparation stage. Errors in drug administration most commonly involved incorrect rate ($n = 84$; 48.3%) or incorrect timing ($n = 70$; 40.2%). Table 3 presents details related to the medication errors observed. The medications most commonly associated with errors were electrolytes and fluids (11.6%), anti-infective agents (8.9%), drugs used to treat the respiratory system (4.7%), antithrombotic agents (3.4%), and analgesics (2.6%).

Table 2 Patient characteristics

Characteristic	Categories	Patients *N* (%)
Birth weight	Extremely low birth weight (≤ 1000 g)	32 (19.5)
	Very low birth weight (1001–1499 g)	26 (15.9)
	Low birth weight (1500–2499 g)	56 (34.1)
	Normal birth weight (≥ 2500 g)	50 (30.5)
Gestational age	Extremely preterm (< 32.0 weeks)	70 (42.7)
	Late preterm (32.0–36.6 weeks)	47 (28.7)
	Term (≥ 37.0 weeks)	47 (28.7)
Level of critical care required	1A (nurse resources: 1 nurse/1 patient)	18 (11.0)
	1B (nurse resources: 1 nurse/2 patients)	41 (25.0)
	2 (nurse resources: 1 nurse/2–3 patients)	105 (64.0)
Ventilation	Mechanical	40 (24.4)
	Continuous positive airway pressure	84 (51.2)
	Room air	40 (24.4)

Method comparison

Only two medication errors were recorded in the ProGREI database during the study period, accounting for 0.01 errors each patient-day. These two errors were declared and recorded by nurses in ProGREI and were also observed directly by the clinical pharmacist. These two errors were related to drug administration and classified as minor.

Risk factors

In multivariate analysis, two factors were significantly related to increased risk for medication errors: number of drugs prescribed (incidence rate ratio, 1.19; $p < 0.01$) and gestational age < 32.0 weeks (compared to gestational age > 37.0 weeks (incidence rate ratio, 1.61; $p = 0.04$)) (Table 4). In comparison to newborns with normal weight (≥ 2500 g), newborns with low birth weight (1500–2499 g) were at greater risk for preparation errors (incidence rate ratio, 2.69; $p = 0.03$). This association was not observed for prescription or administration errors.

Compared to full-term newborns (> 37.0 weeks), those born extremely early (gestational age < 32.0 weeks) were at significantly greater risk for errors of moderate severity (incidence rate ratio, 5.97; $p = 0.02$). The risk for an error of moderate severity increased as the number of prescribed medications increased (incidence rate ratio for one unit, 1.15, $p = 0.01$). Error severity varied significantly among various stages of the medication process. The rate of errors of moderate severity was higher during the administration stage (24.1%) than during the prescription (10.9%) or preparation (1.6%) stages ($p < 0.01$). There was no correlation between birth weight, mode of ventilation, or disease severity and higher overall risk for medication error or risk for errors of moderate severity.

Discussion

Types of medication errors

Our study showed that medication errors in our NICU are frequent (234 medication errors per 100 admissions) and affect a large proportion of hospitalised newborns (84.8%). Medication errors occurred more frequently during administration (45.4%) and prescription (38.4%); these results are in agreement with reported observations [5, 19].

The overall rate of medication errors observed in the present study was higher than figures reported previously by Bates et al. [1] (140 per 100 admissions), Kaushal et al. [14] (55 per 100 admissions), and Snijders et al. [26] (37 per 100 admissions). There are several possible explanations for the discrepancy among these results: a more sensitive method for detecting errors (i.e. chart review, prospective direct observation, or incident

Table 3 Medication errors classified according to the taxonomic system proposed by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP)

Stage	Type of medication error	Direct observation				Voluntary report *N* (%)
		2010 *N* (%)	2012 *N* (%)	Total 2010–2012 *N*	*p* value	
Prescription	Dose omission	17 (42.5)	23 (57.5)	40	0.52	0 (0.0)
	Improper dose	18 (58.1)	13 (41.9)	31	0.28	0 (0.0)
	Incorrect drug name	27 (96.4)	1 (3.9)	28	< 0.01	0 (0.0)
	Incorrect route of administration	1 (9.1)	10 (90.9)	11	0.01	0 (0.0)
	Drug not necessary	5 (50.0)	5 (50.0)	10	1.00	0 (0.0)
	Incorrect dose interval	9 (90.0)	1 (10.0)	10	< 0.01	0 (0.0)
	Incorrect unit	4 (66.7)	2 (33.3)	6	0.44	0 (0.0)
	Incorrect drug	4 (100.0)	0 (0.0)	4	0.05	0 (0.0)
	Incorrect strength/concentration	4 (100.0)	0 (0.0)	4	0.05	0 (0.0)
	Incorrect rate (continuous or intermittent iv drug)	2 (100.0)	0 (0.0)	2	0.23	0 (0.0)
	Incorrect volume calculation	0 (0.0)	1 (100.0)	1	1.00	0 (0.0)
	Total	91 (61.9)	56 (38.1)	147	< 0.01	0 (0.0)
Preparation	Incorrect volume of diluent	0 (0.0)	19 (100.0)	19	< 0.01	0 (0.0)
	Poor adherence to aseptic technique	8 (44.4)	10 (55.6)	18	0.47	0 (0.0)
	Incorrect preparation technique	4 (23.5)	13 (76.5)	17	0.01	0 (0.0)
	Incorrect diluent	3 (75.0)	1 (25.0)	4	0.63	0 (0.0)
	Incorrect volume of active ingredient	1 (25.0)	3 (75.0)	4	0.33	0 (0.0)
	Total	16 (25.8)	46 (74.2)	62	< 0.01	0 (0.0)
Administration	Incorrect rate	35 (41.7)	49 (58.3)	84	0.01	1 (50.0)
	Incorrect timing	41 (58.6)	29 (41.4)	70	0.53	0 (0.0)
	Dose omission	5 (41.7)	7 (58.3)	12	0.39	0 (0.0)
	Incorrect technique	2 (50.0)	2 (50.0)	4	1.00	0 (0.0)
	Incorrect route	1 (50.0)	1 (50.0)	2	1.00	0 (0.0)
	Extra dose	0 (0.0)	1 (100.0)	1	0.45	1 (50.0)
	Incorrect dosage form	0 (0.0)	1 (100.0)	1	0.45	0 (0.0)
	Total	84 (48.3)	90 (51.7)	174	0.06	2 (100.0)
	Total errors	191 (49.9)	192 (50.1)	383	0.48	2

Table 4 Explicative variables in multivariate Poisson regression for total medication errors

Response variable	Explicative variable	Values	Incidence rate ratio	*p* value
Total medication errors	Birth weight	< 1000 g	0.65	0.11
		1000–1499 g	0.67	0.12
		1500–2499 g	0.98	0.90
	Gestational age	< 32 weeks	1.61	0.04
		32–37 weeks	1.06	0.76
	Severity of the disease	1B (nurse resources: 1 nurse/2 patients)	1.21	0.30
		2 (nurse resources: 1 nurse/2–3 patients)	1.45	0.13
	Mode of ventilation	Continuous positive airway pressure	1.32	0.07
		Mechanical	1.34	0.24
	Number of prescription		1.19	< 0.01
	Year 2012		0.96	0.71

reports), the definition of medication error, and the experience together with an increased sensitisation of the observer.

The most frequent errors observed were incorrect rate of administration (84, 21.9%), incorrect timing of administration (70, 18.3%), dose omission (40, 10.4%), and improper dose (31, 8.1%). These errors resulted mainly from distractions or failure to pay attention at critical moments, also called "automatic mode errors" [7]. These errors include for example incorrect flow rates programming on infusion pumps, intravenous bolus administrations of anti-infective drugs instead of administering them in 3 to 5 min, or the omission to prescribe vitamins with total parenteral nutrition. In total, 71.0% of all medication errors observed were *automatic mode* errors and 29.0% were *problem-solving mode* errors. The latter arises because of lack of knowledge or because of misinterpretation of the problem [7]. Simplifying and standardising the medication process by removing time-consuming or repetitive steps and by implementing information technologies, such as smart-pumps or computerised physician order entry, that help physicians and nurses to maintain concentration while prescribing, preparing, and administering drugs would help to decrease errors caused by insufficient attention [16, 20, 29]. The extension of continuous drug infusions beyond 24 h would also reduce the number of daily drug preparations and administrations by nurses and therefore the potential of errors.

Most medication errors observed in the present study were minor, with no consequences for patients. Few errors (15.4%) required the initiation of routine-specific therapy or close monitoring of the patient. No error in the present study resulted in death or a need for resuscitation, thereby confirming fortunately the rarity of serious errors [18, 27].

Method comparison

The comparison of number of medication errors declared by caregivers in *ProGREI* and those identified by the clinical pharmacist through direct observation shows that only 0.5% of the 383 medication errors detected by the clinical pharmacist were actually declared and recorded by nurses and physicians in our incident reporting system. This result shows clear underreporting of medication errors, despite the promotion of a culture of error in our Clinic of Neonatology for nearly 20 years. Underreporting is a weakness of the voluntary anonymous declaration system [8, 13]. Errors occurring during prescription were underreported. When physicians make a prescribing error, it is usually corrected by the physicians themselves or signalled by nurses and then corrected by physicians, without any incident recorded in the system. Other possible reasons for this underreporting of medication errors are the interpretation of the medication error definition by each caregiver and the need to report only errors that ultimately affected patients. Thus, the results of direct observation reveal that the underreporting of medication errors by caregivers contributes to a loss of information related to the medication process, in particular at the prescription and administration stages.

Risk factors

Several factors were related to an increased frequency of medication errors. As expected, errors during the prescription, preparation, and administration stages, as well as total medication errors, increased when the number of drugs prescribed increased (incidence rate ratio, 1.19; $p < 0.01$). Each additional drug prescription increased the risk of error during prescription, preparation, or administration (incidence rate ratio, 1.24, 1.09, and 1.17, respectively). Thus, each prescribed drug must be clinically justified. Prescriber must be aware that each additional drug prescribed increases the risk for medication error and the severity for the patient. An inverse relation was observed between gestational age and rate of medication errors. The number of medication errors was significantly higher in extremely preterm newborns (gestational age < 32.0 weeks) compared with term newborns (gestational age > 37.0 weeks) (incidence rate ratio, 1.61; $p = 0.04$). Extremely preterm newborns were more affected by errors of moderate severity than were other age groups (incidence rate ratio, 5.97; $p = 0.02$). This finding is consistent with a report by Kugelman et al. [15], which described a higher rate of iatrogenic events in newborns with gestational ages of 24 to 27 weeks, compared with term newborns. Medication errors were no more common among newborns with low birth weight, severe disease (1A), or requirement for invasive ventilation compared with controls.

A new, preformatted medical order sheet was introduced during the period from 2010 to 2012. In a previous study, Palmero et al. [24] showed that the rate of prescription errors decreased significantly from 28.9 to 13.5% ($p < 0.05$) after the introduction of the new medical order sheet. Although the introduction of the new medical order sheet decreased prescription errors in the present study, this intervention did not affect total medication errors ($p = 0.77$).

This study had certain limitations. The design of our study as well as an observation period of only 24 h for each patient did not allow us to evaluate the accuracy of incident reports. Observations during the night shift and on weekends, when the workforce was smaller, were not recorded and, therefore, not analysed. When selecting physicians and nurses to participate in the study, we did not quantify professional experience in an NICU environment or consider knowledge of neonatal drug therapy.

Conclusion

Medication errors are frequent and occur at each stage of the medication process. However, medication errors were underreported by NICU caregivers at our hospital. The

attitude of doctors and nurses towards reporting needs to be changed. Most medication errors were "automatic mode" errors and could likely have been prevented by simplifying the medication process and implementing interventions to help physicians and nurses maintain their concentration. Risk for medication error increased with the number of prescribed medications. Low gestational age was associated with an increased risk of medication errors and more serious consequences. Medication error incidence rate was not affected by birth weight, mode of ventilation, or disease severity.

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Authors' contribution D. Palmero, E.R. Di Paolo, A. Pannatier, F. Sadeghipour and J.-F. Tolsa designed the study. D. Palmero made the observations and collected the data. D. Palmero, E.R. Di Paolo and C. Stadelmann analyzed the data. D. Palmero wrote the manuscript. All authors contributed to and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The Ethics Committee for Human Research of Canton Vaud approved the study protocol before the enrolment of the first patient.

Animal studies This article does not contain any studies with animal performed by any of the authors.

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