Patterns of medication errors involving pediatric population reported to the French Medication Error Guichet

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INTRODUCTION

In 1999, the Institute of Medicine published its landmark report “To Err is Human”, which estimated that, in the United States, 44,000 to 98,000 deaths annually are due to medical errors, with 7,000 deaths attributable to medication errors.1 Since this publication, interest in medication errors has increased dramatically.2,4 Two decades later, medication errors are still estimated to injure approximately 1.3 million people in the United States annually.5 In England, out of the estimated 237 million medication errors per year, 27.8% have the potential to cause moderate and severe harm.6 In France, the Enquête Nationale sur les Evénements Indésirables graves liés aux Soins (ENESIS) study revealed that 42% of serious adverse drug events are preventable.7 In response to this problem, the World Health Organization (WHO) launched in 2017 its “Global Patient Safety Challenge on Medication Safety - Medication Without Harm” aiming to reduce severe, avoidable medication-associated harm by 50% over the next five years, specifically by prioritizing and effectively managing “high-risk situations”.8

Although medication errors constitute a major concern in different age groups, children are distinctive prone to this problem.9 Several factors heighten risk of medication errors in pediatrics, primordially the weight-based dosing that involves multiple calculations, in addition to the lack of appropriate pediatric formulations.9 11 A recent systematic

Abstract

Background: Medication error is a global threat to patient safety, particularly in pediatrics. Yet, this issue remains understudied in this population, in both hospital and community settings.

Objectives: To characterize medication errors involving pediatrics reported to the French Medication Error Guichet, and compare them with medication errors in adults, in each of the hospital and community settings.

Methods: This was a retrospective secondary data analysis of medication errors reported throughout 2013-2017. Descriptive and multivariate analyses were performed to compare actual and potential medication error reports between pediatrics (aged <18 years) and adults (aged >18 and <60 years). Two subanalyses of actual medication errors with adverse drug reaction (ADR), and serious ADR were conducted.

Results: We analyzed 4,718 medication error reports. In pediatrics, both in hospital (n=791) and community (n=1,541) settings, antibacterials for systemic use (n=121, 15.7%; n=157, 10.4%, respectively) and wrong dose error type (n=391, 49.6%; n=549, 35.7%, respectively) were frequently reported in medication errors. These characteristics were also significantly more likely to be associated with reported errors in pediatrics compared with adults. In the hospital setting, analgesics (adjusted odds ratio [aOR]=1.59; 95% confidence interval [CI] 1.03:2.45), and blood substitutes and perfusion solutions (aOR=3.74; 95%CI 2.24:6.25) were more likely to be associated with reported medication errors in pediatrics; the latter drug class (aOR=3.02; 95%CI 1.59:5.72) along with wrong technique (aOR=2.28; 95%CI 1.01:5.19) and wrong route (aOR=2.74; 95%CI 1.22:6.15) error types related more to reported medication errors in serious ADR in pediatrics. In the community setting, the most frequently reported pediatric medication errors involved vaccines (n=389, 25.7%). Psycholeptics (aOR=2.42; 95%CI 1.36:4.31) were more likely to be associated with reported medication errors with serious ADR in pediatrics. Wrong technique error type (aOR=2.71; 95%CI 1.47:5.00) related more to reported medication errors with ADR in pediatrics.

Conclusions: We identified pediatric-specific medication error patterns in the hospital and community settings. Our findings inform focused error prevention measures, and pave the way for interventional research targeting the needs of this population.

Keywords

Medication Errors; Patient Safety; Drug-Related Side Effects and Adverse Reactions; Adverse Drug Reaction Reporting Systems; Pharmacovigilance; Pharmacoepidemiology; Child; Infant; Multivariate Analysis; Retrospective Studies; France

Reference

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Accepted: 30 May 2021

https://doi.org/10.18549/PharmPract.2021.2.2360
Patterns of medication errors in pediatrics are understudied in the hospital and community settings.\textsuperscript{14,15} Besides, using information from studies conducted on adults may be of limited value, since medication errors most likely differ between the two populations.\textsuperscript{16,17} Exploring specific patterns of medication errors in pediatrics compared with adults could enhance our understanding of this complex problem in pediatrics and inform targeted efforts to enhance patient safety.

In France, a national medication error reporting system, the French Medication Error Guichet, which is managed by the National Agency for Medicines and Health Products Safety, allows the collection of reported medication errors.\textsuperscript{18} Our study aimed to characterize the medication errors reported to the French Medication Error Guichet in pediatrics aged less than 18 years, and compare them with medication errors in adults, in each of the hospital and community settings.

**METHODOLOGY**

**Study design**

We performed a retrospective secondary data analysis of the medication errors reported to the French Medication Error Guichet over a five-year period from 2013 to 2017.

**Definitions**

According to the French National Agency for Medicines and Health Products Safety, medication error was defined as an unintentional omission or commission of an act during the care process involving a drug, which may cause a risk or an adverse event for the patient.\textsuperscript{19} There were three classifications for medication errors:

- Actual medication error is an error that occurred and reached the patient.\textsuperscript{20} It may be associated or not with an adverse drug reaction (ADR).
- Potential medication error is an error that is intercepted before the administration of the medication to the patient.\textsuperscript{20} Therefore, potential medication error does not allow analysis on ADRs.
- Medication error risk is an observation that witnessed a potential danger to the patient.\textsuperscript{20} The patient description (age, gender) and error characterization (stages, types) are not applicable in case of error risk. Consequently, medication error risk does not allow an age-based analysis.

The age group categories followed the classification adopted by the French Medication Error Guichet: pediatrics (age <18 years), adults (age >18 and <60 years), and geriatrics (age >60 years).

**Inclusion/exclusion criteria**

All actual and potential medication error reports involving pediatric and adult populations submitted to the French Medication Error Guichet between 2013 and 2017 were included in the analysis.

Reports of medication error risk, reports of medication errors involving geriatric population, and reports with unknown patient age or error setting were excluded from the analysis.

**Data sources**

The French Medication Error Guichet is a centralized database for collecting all medication error reports (medication error risk, potential, and actual medication errors) occurring in France. Medication errors were reported by the regional pharmacovigilance centers network, pharmaceutical laboratories, healthcare professionals, and patients. Medication errors without ADRs were reported voluntarily. However, medication errors with ADRs were reported on a mandatory basis for healthcare professionals, through the regional pharmacovigilance centers network.

**Data collection**

Collected data included the person who reported the error (profession, workplace of the declarant), patient (gender, age), error description (date of occurrence, setting, classification, stages, types, and causes), products involved (drug classes, dosage, and routes of administration), and error consequence (presence or absence of an ADR and its seriousness).

The error setting referred to the place of occurrence of the error, i.e., hospital or community setting. The latter included homes, medical-social institutions, community pharmacies, and outpatient clinics. The stages of the medication-use process were classified as prescribing, dispensing, preparation, administration, and others (including monitoring error). The types of error were categorized as per the French National Agency for Medicines and Health Products Safety: wrong drug, wrong dose, wrong technique, wrong route, wrong patient, wrong duration/time, expired, deteriorated or not well conserved drug, and other medication errors (omission error, wrong rate, and other types defined as any error not fitting into the above pre-specified categories). The causes of error were categorized as related to products, healthcare professionals, patients, or to the computerized system, based on the classification of the Société Française de Pharmacie Clinique for medication error causes.\textsuperscript{21} The medications involved in errors were classified according to the WHO Anatomical Therapeutic Chemical (ATC) classification system second level.\textsuperscript{22} Regarding the seriousness, an ADR associated with medication error was considered serious if it meets one or more of the following pharmacovigilance criteria: results in death, is life-threatening, requires inpatient hospitalization or prolongation of existing hospitalization, results in persistent or significant disability or incapacity, results in a congenital anomaly (birth defect), or is otherwise medically significant (i.e., effect judged as serious by a healthcare professional).\textsuperscript{19}
Data cleaning

The quality and consistency of data were verified by reviewing the error description text within each medication error report and if needed, by reclassifying medication error stage, type, cause, or severity. In addition, any incompleteness or missing data were cross-checked against the original report.

Statistical analysis

Descriptive results were presented as frequencies and percentages. To compare the reported medication errors between pediatric and adult populations, we performed bivariate and multivariate analyses in the hospital and community settings. In each setting, a logistic regression analysis using Backward Stepwise method was performed. Two subanalyses limited to actual medication errors with ADR, and actual medication errors with serious ADR were also conducted in each setting. The independent variables concerned the medication errors characteristics (drug classes, routes of administration, classification in terms of actual or potential medication error, stages, types, and causes of error). The characteristics that had a p-value <0.2 in the bivariate analysis were included in the logistic regression model in which pediatric versus adult reported medication error was the dependent variable. Multivariate analyses were systematically adjusted for the reporting year, source of declarations (including the regional pharmacovigilance centers network, pharmaceuticals laboratories, healthcare professionals, and patients), and gender. The strength of association between the dependent variable and each independent variable was assessed by calculating the adjusted odds ratio (aOR) and its respective 95% confidence interval (CI). The p-values...
<0.05 were considered statistically significant. Statistical analyses were performed using the SPSS version 20. As our analysis intended to generate age- and setting-specific results, reports with missing data for these variables were excluded.

**Ethical considerations**

Medication errors data were presented anonymously in the database. An authorization was granted from the Commission Nationale de l’Informatique et des Libertés to the National Agency for Medicines and Health Products Safety to manage the French Medication Error Guichet.

**RESULTS**

Between 2013 and 2017, 12,136 medication error reports were submitted to the French Medication Error Guichet. The flowchart of the reports is detailed in Figure 1. Among the 12,136 total medication error reports, 1,322 reports of medication error risk, and 2,593 reports involving geriatric medication error risk, and 2,163 reports with unknown age data were excluded. Finally, 4,718 reports on actual and potential medication errors were included. Between 2013 and 2017, 12,136 medication error reports were submitted to the French Medication Error Guichet. The flowchart of the reports is detailed in Figure 1. Among the 12,136 total medication error reports, 1,322 reports of medication error risk, and 2,593 reports involving geriatric medication error risk, and 2,163 reports with unknown age data were excluded. Finally, 4,718 reports on actual and potential medication errors were included.

### Table 1. Comparison of actual and potential medication error reports in hospital setting between pediatric and adult populations

| Medication errors characteristics | Adult (N=779), n (%) | Pediatric (N=791), n (%) | aOR [95% CI] | p-value |
|----------------------------------|----------------------|--------------------------|--------------|---------|
| **Drug classes**                 |                      |                          |              |         |
| Other ATC classes                | 504 (65.5)           | 387 (50.3)               | Reference    | N/A     |
| J01 (Antibacterials for systemic use) | 61 (7.9)            | 121 (15.7)              | 2.54 [1.57:4.11] | <0.001 |
| NO2 (Analgesics)                | 73 (9.5)             | 104 (13.5)              | 1.59 [1.03:2.45] | 0.035 |
| B05 (Blood substitutes and perfusion solutions) | 34 (4.4) | 94 (12.2) | 3.74 [2.24:6.25] | <0.001 |
| N05 (Psycholeptics)             | 68 (8.8)             | 33 (4.3)                | 0.72 [0.42:1.26] | 0.252 |
| N03 (Antiepileptics)            | 30 (3.9)             | 31 (4)                  | 1.55 [0.82:2.95] | 0.179 |
| **Routes of administration**    |                      |                          |              |         |
| Oral route                       | 245 (34.5)           | 195 (25.3)              | Reference    | N/A     |
| Injectable route                 | 436 (61.4)           | 453 (56.5)              | 1.03 [0.74:1.42] | 0.880 |
| Others                           | 29 (4.1)             | 40 (5.8)                | 2.14 [1.10:4.18] | 0.026 |
| **Stages of error**             |                      |                          |              |         |
| Administration                   | 584 (75.2)           | 565 (71.5)              | N/A          | N/A     |
| Prescribing                      | 128 (16.5)           | 123 (15.6)              | N/A          | N/A     |
| Preparation                      | 26 (3.3)             | 56 (7.1)                | N/A          | N/A     |
| Dispensing                       | 28 (3.6)             | 36 (4.6)                | N/A          | N/A     |
| Others (including monitoring error) | 11 (1.4)          | 10 (1.3)                | N/A          | N/A     |
| **Types of error**               |                      |                          |              |         |
| Wrong drug (including wrong form) | 189 (24.3)          | 150 (19)                | Reference    | N/A     |
| Wrong dose                       | 252 (32.4)           | 391 (49.6)              | 2.51 [1.71:3.68] | <0.001 |
| Wrong technique                  | 49 (6.3)             | 54 (6.8)                | 1.18 [0.66:2.10] | 0.578 |
| Wrong route                      | 43 (5.5)             | 41 (5.2)                | 1.71 [0.94:3.13] | 0.082 |
| Expired, deteriorated or not well conserved drug | 9 (1.2)             | 25 (3.2)                | 5.16 [1.78:15.0] | 0.003 |
| Wrong duration/ wrong time       | 30 (3.9)             | 16 (2)                  | 1.11 [0.48:2.58] | 0.807 |
| Wrong patient                    | 55 (7.1)             | 15 (1.9)                | 0.51 [0.22:1.18] | 0.116 |
| Others (omission error, wrong rate, other types) | 150 (19.3)          | 97 (12.3)               | 0.93 [0.59:1.49] | 0.773 |
| **Related causes**               |                      |                          |              |         |
| Product                          | 85 (11.4)            | 106 (13.8)              | Reference    | N/A     |
| Healthcare professionals         | 562 (75.1)           | 590 (76.6)              | 1.48 [0.92:2.38] | 0.105 |
| Patient                          | 52 (7)               | 33 (4.3)                | 0.84 [0.40:1.74] | 0.630 |
| Computerized system              | 41 (5.5)             | 33 (4.3)                | 0.74 [0.28:1.93] | 0.531 |
| Others                           | 8 (1.1)              | 8 (1)                   | 1.53 [0.28:8.46] | 0.629 |

aOR: adjusted odds ratio; ATC: Anatomical Therapeutic Chemical classification system; CI: confidence interval; N/A: not applicable (reference or excluded from the final model).

1The sum of the frequencies in each group of population may be less than the total number of reports in this group due to missing data.

2The multivariate analysis was adjusted for year, source of declarations and gender.
The results of the subanalysis concerning actual medication errors with ADR showed that antibacterials for systemic use (aOR=1.92; 95% CI 1.13:3.26), analgesics (aOR=1.63; 95% CI 1.05:2.53), blood substitutes and perfusion solutions (aOR=3.75; 95% CI 2.18:6.47) were significantly more likely to be associated with reported medication errors with ADR in pediatric compared with adults. Regarding error types, wrong dose (aOR=2.73; 95% CI 1.82:4.09) and wrong route (aOR=3.11; 95% CI 1.57:6.19) were significantly more likely to be associated with reported medication errors with ADR in pediatric compared with adults.

The results of the subanalysis of actual medication errors with serious ADR showed that, regarding drug classes, only antibacterials for systemic use (n=157, 10.4%), and analgesics (n=117, 7.7%). The oral route of administration (n=722, 48.9%) was the most commonly involved in the reported medication errors in pediatrics. The administration stage (n=1,214, 78.9%) accounted for the majority of the pediatric medication error reports. The most frequently reported error type in pediatrics was the wrong dose (n=549, 35.7%). Concerning error causes, patient-related causes (n=797, 52.9%) were the most commonly reported in pediatric medication errors. For the adult population, the most commonly reported drug class involved in the medication errors was analgesics (n=260, 16.4%). Besides, the oral route of administration (n=1,057, 69.1%), the administration stage

Table 2. Comparison of actual and potential medication error reports in community setting between pediatric and adult populations

| Medication errors characteristics | Adult (N=1,607), n (%) | Pediatric (N=1,541), n (%) | aOR [95% CI]‡ | p-value |
|----------------------------------|------------------------|-----------------------------|---------------|---------|
| **Drug classes**                 |                        |                             |               |         |
| Other ATC classes                | 841 (53.2)             | 663 (43.8)                  | Reference     | N/A     |
| J07 (Vaccines)                   | 62 (3.9)               | 389 (25.7)                  | 16.3 [9.08:29.2] | <0.001  |
| J01 (Antibacterials for systemic use) | 77 (4.9)           | 157 (10.4)                  | 2.08 [1.46:2.96] | <0.001  |
| N02 (Analgesics)                 | 260 (16.4)             | 117 (7.7)                   | 0.56 [0.43:0.74] | <0.001  |
| D08 (Antiseptics and disinfectants) | 95 (6)                | 109 (7.2)                   | 1.48 [1.01:2.16] | 0.044   |
| N05 (Psychophotics)              | 93 (5.9)               | 69 (4.6)                    | 1.15 [0.79:1.66] | 0.464   |
| G03 (Sex hormones and modulators of the genital system) | 154 (9.7)       | 8 (0.5)                     | 0.08 [0.04:0.17] | <0.001  |
| **Routes of administration**    |                        |                             |               |         |
| Oral                             | 1,057 (69.1)           | 722 (48.9)                  | Reference     | N/A     |
| Injectable route                 | 146 (9.5)              | 430 (29.2)                  | 0.63 [0.39:1.02] | 0.059   |
| Others                           | 327 (21.4)             | 323 (21.9)                  | 1.42 [1.08:1.87] | 0.013   |
| **Stages of error**             |                        |                             |               |         |
| Administration                   | 1,364 (85)             | 1,214 (78.9)                | Reference     | N/A     |
| Dispensing                       | 140 (8.7)              | 152 (9.9)                   | 1.79 [1.18:2.69] | 0.006   |
| Prescribing                      | 69 (4.3)               | 109 (7.1)                   | 1.84 [1.13:3.08] | 0.014   |
| Preparation                      | 15 (0.9)               | 42 (2.9)                    | 2.71 [1.14:4.68] | 0.025   |
| Others (including monitoring error) | 16 (1)                | 19 (1.2)                    | 0.62 [0.24:1.63] | 0.334   |
| **Types of error**              |                        |                             |               |         |
| Wrong drug (including wrong form) | 480 (29.9)           | 445 (28.9)                  | Reference     | N/A     |
| Wrong dose                       | 662 (41.3)             | 549 (35.7)                  | 1.33 [1.04:1.70] | 0.021   |
| Expired, deteriorated or not well conserved drug | 67 (4.2)          | 157 (10.2)                  | 1.32 [0.84:2.07] | 0.225   |
| Wrong technique                  | 56 (3.5)               | 134 (8.7)                   | 2.14 [1.34:4.42] | 0.001   |
| Wrong route                      | 98 (6.7)               | 67 (4.4)                    | 0.74 [0.49:1.13] | 0.167   |
| Wrong duration/ wrong time       | 81 (5)                 | 44 (2.9)                    | 1.56 [0.94:2.59] | 0.084   |
| Wrong patient                    | 33 (2.1)               | 19 (1.2)                    | 0.85 [0.39:1.84] | 0.680   |
| Others (omission error, wrong rate, other types) | 127 (7.9)       | 124 (8.1)                   | 1.34 [0.88:2.04] | 0.167   |
| **Related causes**              |                        |                             |               |         |
| Product                          | 178 (11.4)             | 177 (11.8)                  | Reference     | N/A     |
| Patient                          | 1,089 (69.5)           | 797 (52.9)                  | 1.06 [0.79:1.43] | 0.710   |
| Healthcare professional          | 280 (17.5)             | 514 (34.1)                  | 0.68 [0.44:1.03] | 0.066   |
| Others (including computerized system) | 20 (1.3)            | 18 (1.2)                    | 0.82 [0.33:2.05] | 0.676   |

aOR: adjusted odds ratio; ATC: Anatomical Therapeutic Chemical classification system; CI: confidence interval; N/A: not applicable (reference or excluded from the final model).

The sum of the frequencies in each group of population may be less than the total number of reports in this group due to missing data.

The multivariate analysis was adjusted for year, source of declarations and gender.
We comprehensively described medication errors for systemic use, vaccines, antisepsics and disinfectants, nonoral non-injectable routes of administration, prescribing error, dispensing error, preparation error, wrong dose, and wrong technique were significantly more likely to be associated with reported medication errors in pediatrics compared with adults (Table 2). The breakdown of drug classes frequently reported in actual and potential medication errors in pediatrics, and more likely to be associated with medication errors in pediatrics compared with adults is available in Online appendix Table 4.

The results of the subanalysis of actual medication errors with ADR showed that antiseptics and disinfectants drug class (aOR=1.79; 95%CI 1.25:2.56), dispensing error (aOR=1.54; 95%CI 1.03:2.31), and wrong technique error type (aOR=2.71; 95%CI 1.47:5.00) were significantly more likely to be associated with reported medication errors with ADR in pediatrics compared with adults (Online appendix Table 5). The classification of medication error reports regarding types of ADR in pediatric and adult populations in community setting is available in Online appendix Table 6.

DISCUSSION

We analyzed 4,718 medication errors reported to the national French Medication Error Guichet between 2013 and 2017. We comprehensively described medication errors in pediatrics, and identified pertaining specific patterns, in comparison with adults, in each of the hospital and community settings. We deepened our analyses with an exploration of medication errors with ADR, and serious ADR. Our findings generate important information for future error-prevention measures in pediatrics, and pave the way for interventional research targeting the needs of this population, with the ultimate goal of enhancing patient safety.

Both in hospital and community settings, frequently reported in pediatrics were wrong dose errors, and those involving antibacterials for systemic use. Specifically, these two characteristics were more likely to be associated with reported medication errors in pediatrics compared with adults. Our findings reiterate the dominance of dosing errors in the pediatric population. For instance, using data from national reporting systems, dosing errors were the most encountered types, accounting for 42.7% of errors in the hospital setting in Denmark, and 62.5% of errors in the community in Ireland. Medication dosing in pediatrics bears a high risk of error, due to the complicated drug doses calculations based on patient’s age, weight, or body surface area, the increased need for drug dilutions and manipulations subsequent to the lack of pediatric formulations, and the presence of multiple dosing devices used for delivering medications at home, possibly leading to confusion. Although these errors are a long-standing problem in pediatrics, the literature does not provide to-date conclusive evidence on effective interventions in this regards. In the hospital setting, computerized physician order entry, unit dose dispensing systems, and educational/risk management programs are suggested to reduce dosing errors. For example, through a recent systematic review of the literature, Gates et al. found that dosing errors were less prevalent in hospitals with computerized physician order entry, but without evidence that this result represented a causal relationship.

In the community setting, through a randomized controlled trial, Yin et al. showed that providing parents with dosing tools more closely matched to prescribed dose volumes, pictographic instructions, and milliliter-only units on labels and tools are promising strategies for reducing pediatric dosing errors. There is a pressing need for research employing robust controlled designs to assess the true impact of different interventions on dosing errors and associated harm to patients.

The involvement of antibacterials for systemic use in pediatric medication errors is also commonly reported elsewhere, with proportions reaching 27.2% in the hospital setting and 17% in the community. Antibiotics are extensively used in pediatrics, and subject to overtreatment through pressure from parents on clinicians to prescribe them. These factors potentially explain the common involvement of antibacterials in reported medication errors. A French study using a national reimbursement claims database showed that half (49%) the children received antibacterials for systemic use. An opportunity may exist in decreasing unnecessary exposure to antibacterials, and the medication errors that occur with their use.

In our analysis, administration stage topped the reported medication errors in adult and pediatric populations, in both settings. The common citation of administration errors is probably because they are the most visible and closest to the patient. Specifically, our findings in pediatrics are supported by other studies. Through a systematic review of the literature, Miller et al. found administration error occurrence between 72 and 75 in every 100 reported medication errors. Recent estimates also highlight this issue, whereby administration errors accounted between 42.5% and 54% of pediatric medication errors. Of interest, Kaushal et al. found that harmful errors occurred most commonly at the drug administration stage by parents. Interventional studies in hospital medication administration errors explored barcode medicine administration, electronic prescribing, education and training, use of smart pumps, and standard concentration. However, evidence is not conclusive regarding their impact or effects on reducing errors. In the community, all caregivers including parents, extended family members, and school nurses should be adequately trained on how to appropriately administer the medication to children.

In the hospital setting, our findings of analgesics, and blood substitutes and perfusion solutions being frequently reported in medication errors in pediatrics are in line with...
For instance, in the national study by Rishoej et al., both of these drug classes were commonly involved in reported medication errors, with respective proportions of 13% and 6%. Of interest, our comparison with reported medication errors in adults indicates that errors involving analgesics, and blood substitutes and perfusion solutions related more to pediatrics. Through an observational study, Jimenez et al. also found that pediatrics had higher medication errors related to electrolytes and total parenteral nutrition compared with adults (19.9% vs. 8.3%). Accordingly, prevention strategies targeting analgesics, and blood substitutes and perfusion solutions may considerably enhance pediatric patient safety, especially that these classes encompass high-alert medications in pediatrics, such as opioids, and parenteral nutrition. Within this scope, we identified that blood substitutes and perfusion solutions related more to reported medication errors with serious ADR in pediatrics. For instance, one of the described serious ADRs was electrolyte disorders such as hyperkalemia or hyperglycemia resulting from errors with solutions for parenteral nutrition (data not shown).

In line with the literature, wrong route and wrong technique error types were not commonly reported in pediatric and adult medication errors in hospital settings. Importantly, our findings suggest that these error types were more likely to be associated with reported medication errors with serious ADR in pediatrics compared with adults. Data from the Finnish Poison Information Centre indicate that incorrect route of administration error type occurred mainly in hospitals. This type resulted in the most serious medication errors. Children under 10 years of age were particularly exposed to this error type.

In the community setting, vaccines were the drug class most frequently involved in reported errors in pediatrics. Common involvement of vaccines in pediatric medication errors was also reported elsewhere. This comes parallel to the substantial exposure to vaccinations throughout early childhood, and the complex vaccination schedule. Using data from the United Kingdom National Reporting and Learning System, the study of Rees et al. conducted to characterize the pediatric safety incidents occurring in family practice, found that vaccine-related incidents were the most frequently described, with wrong time, wrong dose, and wrong vaccine error types, being the most frequently reported. These vaccination incidents resulted in harm in 70.6% of cases. Vaccines are nonemergency drugs given in specific, controlled circumstances, and pertaining error types are associated with predictable vaccine-related human factors challenges; the targeting of which presents a valuable opportunity to prevent errors.

This study adds evidence that medication errors involving analgesics are commonly reported in pediatrics in the community. Nevertheless, our analysis showed that these agents were less likely to be associated with reported medication errors in pediatrics compared with adults. In contrast, although psycholeptics were infrequently reported in community pediatric medication errors, we observed elsewhere, our study found that they related more to reported medication errors with serious ADR in pediatrics compared with adults. Based on the National Poison Data System in the United States from 2000 to 2012, Kamboj et al. found that atypical antipsychotics—a group of psycholeptics were associated with 32.1% of medication errors among children aged 6 to 19 years, compared with 20.6% among adults aged 20 years or above. Our results thus join the emerging literature in suggesting a pediatric-specific pattern concerning medication errors involving psycholeptics. Finding effective targeted strategies for reducing pertaining medication errors and associated harm is crucial.

Noteworthy, we report a discordance with the former literature concerning medication errors involving cough and cold preparations. While this drug class was previously commonly involved in medication errors in children in the community, it was not identified as such in our analysis. Smith et al., in their study spanning 2002–2012, showed a sharp decline in both the frequency and rate of errors involving cough and cold preparations from 2005 through 2012. Decline in pertaining errors could be related to the decreased use of these agents, which might be attributed to the recommendation against the use of over-the-counter cough and cold preparations among young children. Indeed, recent evidence did not identify these agents in reported medication errors in pediatrics.

In the community, wrong technique error type was not frequently reported in pediatrics; yet, our comparative analysis showed that this error type is pediatric-specific, relating more to reported medication errors, as well as medication errors with ADR in this population. This may be explained by the increased need for drug manipulation in pediatric care that is mainly driven by the lack of commercially-available, age-appropriate formulations. Other reasons include parents misunderstanding medication preparation instructions, or altering the technique for administration from the physician instructions due to the lack of proper equipment, or because the recommended technique did not work at home. Suggested actions include interventions to enhance carers’ understanding of administration techniques through proper and precise instructions, having appropriate equipment at home, in addition to routine provider inquiry about problems in daily medication use.

Finally, as medication errors were reported throughout the medication use process in both settings, involvement of all actors along the continuum of care is crucial to ensure patient safety.

**Strengths and limitations**

This study is the first to comprehensively analyze pediatric medication errors reported to the French Medication Error Guichet, over a five-year period. Using a large national database, this study allowed delineating pediatric-specific medication error patterns in comparison with adults, in each of the hospital and community settings. Furthermore, we complemented our results with comparative analyses of reported medication errors with ADR and serious ADR. The analysis bore numerous challenges including the use of retrospective secondary data based on a reporting
CONCLUSIONS

Pediatrics are not little adults; they require particular attention in medication use. Our study characterized medication errors in pediatrics, and identified specific medication error patterns in this population, compared with adults. Drug classes particularly implicated in pediatric medication errors included antibacterials for systemic use, analgesics, blood substitutes and perfusion solutions, vaccines, and psycholeptics. Other error-prone areas involved primarily the administration stage; in addition to wrong dose, wrong technique, and wrong route types. Our results hold important implications for health professionals, caregivers, manufacturers, and policy makers, as well as researchers with respect to focused measures to enhance pediatric medication safety.

ACKNOWLEDGMENTS

We acknowledge Frederic Rannou from the French National Agency for Medicines and Health Products Safety, for technical assistance in extracting the data. We also acknowledge the important contributions of the Regional Pharmacovigilance Centers network in data collection.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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