AJPMHS GLOBAL RESEARCH NETWORK

AMERICAN Journal of Pediatric Medicine and Health Sciences
Volume 4, Issue 9, 2026 ISSN (E): 2993-2149

Medication Errors in a Handwritten Paper-Based Medication Workflow at a Pediatric Hospital in Kirkuk, Iraq: A Prospective Observational Study

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Abstract: Medication errors are an important patient-safety concern in pediatric hospitals, particularly in handwritten, paper-based medication systems where incomplete information, calculation mistakes, illegible prescriptions, and administration errors may occur. Children are especially vulnerable because many medications require weight-based dose calculations. A prospective observational study was conducted in a children's hospital in Kirkuk, Iraq, during 2026. Five pharmacists working in different hospital wards reviewed handwritten medication orders and administration records during a one-month observation period between March and May. Errors were documented and corrected during pharmacist double-checking before medicines reached patients. Patient-level missing-weight documentation and medication-related error events were analyzed separately using IBM SPSS Statistics version 26.0. Among 650 pediatric patients and 3,350 medications reviewed, 54 patients (8.31%) had missing weight documentation. An additional 293 medication-related error events were identified (8.75 events per 100 medications reviewed), giving 347 recorded safety observations in total. Administration-related events accounted for 171 of the 293 medication-related events (58.36%), followed by prescribing (80; 27.30%) and dispensing (42; 14.33%). Missed administration time was the most frequent medication-related error (142/293; 48.46%). All 347 recorded problems were detected and corrected before reaching patients. Pharmacist double-checking intercepted all documented errors before patient exposure. Mandatory weight recording, standardized paper medication charts, dose verification, and clear administration schedules may improve safety in pediatric paper-based workflows.

Keywords: Pediatric medication safety, Medication errors, Paper-based workflow, Pharmacist double-checking, Kirkuk Iraq

Introduction

Medication errors are preventable events that may result in inappropriate medication use or patient harm and can occur at different stages of the medication-use process, including prescribing, communication of medication orders, dispensing, preparation, administration, and monitoring [1]. Medication-related harm represents a substantial global patient-safety burden. The World Health Organization (WHO) reported that harm associated with medicines and therapeutic interventions accounts for nearly half of preventable harm occurring in medical care [2]. Medication errors may result in therapeutic failure, adverse drug events, additional monitoring or treatment, prolonged hospitalization, increased healthcare costs, permanent injury, and, in severe cases, death. Importantly, not every medication error results in harm because some errors are detected and corrected before reaching the patient; nevertheless, identifying these errors is essential because they reveal weaknesses in the medication-use system that may lead to future patient harm [2,3].

Paper-based and handwritten medication systems remain particularly vulnerable to errors related to illegible handwriting, incomplete information, non-standard abbreviations, incorrect doses or units, and misinterpretation during communication between physicians, pharmacists, and nurses. A recent comparative hospital study found a prescribing-error rate of 5.92% with handwritten prescriptions, which declined to 1.92% three months and 1.39% six months after implementation of computerized provider order entry; errors related to illegibility, non-standard abbreviations, and incomplete prescriptions were eliminated after electronic prescribing was introduced [4]. These problems are of particular concern in children's hospitals, where medication orders frequently require individualized dose calculations. In a prospective pediatric inpatient study, medication administration errors causing actual harm were reported to be 45% less frequent when an electronic medication-management system was used compared with paper medication charts, highlighting the potential safety limitations of paper-based medication workflows [5].

Children are particularly susceptible to the consequences of medication errors because drug doses often need to be individualized according to body weight, age, clinical condition, route of administration, and available formulation. These additional calculations increase the possibility of underdosing, overdosing, decimal-point errors, incorrect concentrations, and inappropriate dosing frequencies [6]. A 2025 systematic review reported that the prevalence of prescribing errors in pediatric care ranged from 22% to 70% across included studies, with dosing errors being the most frequently reported type, particularly in inpatient and emergency-care settings [6]. Medication errors may produce clinically important harm in children, including inadequate therapeutic response, toxicity, the need for additional treatment or monitoring, and prolonged hospitalization. Recent evidence also indicates that younger children may be particularly vulnerable: in a 2026 study assessing 566 pediatric medication-error cases selected for harm evaluation, actual harm was identified in 89 cases, and younger patients, especially infants younger than 12 months, were at greater risk of harm [7]. These findings emphasize the need for medication-safety systems capable of detecting errors before they reach pediatric patients.

Therefore, the present study aimed to measure the rate and characterize the types of medication errors occurring within a handwritten, paper-based medication workflow in a children's hospital, with particular attention to prescribing and medication-order communication. The study also aimed to determine how frequently identified errors were intercepted before reaching the patient, identify vulnerable points within the existing workflow, and propose practical preventive measures. Such measures may include improved prescription-writing standards, systematic pharmacist review, standardized medication-order forms, staff education, double-checking of high-risk and weight-based doses, and, where feasible, implementation of computerized physician order entry with pediatric clinical decision support, which has shown potential to reduce pediatric dosing errors [8].

Materials and Methods

A prospective observational study was conducted at a children's hospital in Kirkuk, Iraq, during a one-month observation period between March and May 2026. Five pharmacists working in different hospital wards participated. The study focused on errors identified in the existing handwritten, paper-based medication workflow during routine medication-order and administration-record review.

The study was designed to evaluate medication errors under routine clinical practice without modifying the existing medication-prescribing or dispensing system. Pharmacist involvement in medication review represents an important safety barrier because pharmacists can identify medication-related problems and intervene before inappropriate medication use reaches pediatric patients [9,10].

Five pharmacists observed the routine medication workflow in their assigned wards and double-checked handwritten medication orders, medication charts, and scheduled administration details. When a suspected error was detected, it was recorded and corrected in coordination with the

relevant healthcare professional before the medication reached the patient. An intended wrong dose, wrong patient, or missed administration time was counted as an intercepted error when detected during review; it was not counted as an error that had reached the patient.

The recorded variables included the number of patients, medications reviewed, missing patient-weight documentation, the type of medication-related error, and the relevant medication-use phase. Patient-weight documentation was assessed at the patient level, whereas the remaining prescribing, dispensing, and administration errors were recorded as medication-related events. Repeated events involving the same medication were counted as distinct recorded events when applicable; the number of affected medications could not be inferred from the event count alone.

The pharmacists reviewed 650 patients and 3,350 medications. Patient counts served as the denominator for missing-weight documentation, while medications reviewed served as the exposure denominator for the remaining medication-related error-event rate.

A recorded medication error was a preventable discrepancy identified during pharmacist double-checking that could potentially result in inappropriate medication use or patient harm. Missing weight documentation was classified as a patient-level documentation problem. The remaining discrepancies were classified as medication-related error events arising in prescribing, dispensing, or the intended administration process.

All 347 recorded problems, including 54 missing-weight documentation cases and 293 other medication-related events, were detected and corrected through pharmacist double-checking before reaching patients. Labels such as wrong-dose administration and wrong-patient administration describe the intended erroneous administration identified on review, not an error that was completed or reached a patient.

The study reported two outcomes separately: the proportion of patients with missing weight documentation and the medication-related error-event rate per 100 medications reviewed. The measures were calculated as follows:

Missing weight documentation (%) = (54 patients with missing weight / 650 patients reviewed) × 100; medication-related error-event rate = (293 medication-related events / 3,350 medications reviewed) × 100 medications.

Additional outcomes were the count and distribution of medication-related events by type and phase, the number of patients and medications reviewed by pharmacist/ward group, and the proportion of the 347 recorded safety observations that were intercepted before reaching patients. Patient-level weight omissions and medication-related events were not combined into a single medication-based percentage.

The interception proportion was calculated as:

Interception proportion (%) = (recorded problems identified and corrected before patient exposure / all recorded problems) × 100.

The percentage therefore describes interception of the problems observed during pharmacist review, not proof that every error occurring in the hospital was detected.

Data were coded and summarized using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Counts and percentages were reported for patient-level documentation problems and medication-related event categories using the corresponding denominators. Medication-related error-event rates were expressed per 100 medications reviewed; these are event rates, not the percentage of medications or patients affected.

Original group-specific error counts and the previously reported statistical comparison included an incorrect missing-weight total (154 instead of 54). Because the corrected missing-weight counts by pharmacist/ward group were not available in the source document, corrected group-specific error rates, confidence intervals, and between-group significance tests were not reported. No P value from the superseded analysis was carried forward.

The numbers of patients and medications reviewed by each pharmacist/ward group were retained descriptively. A valid comparison of corrected error rates requires the corrected group-level counts of medication-related events and, for a patient-level comparison, the number of distinct patients with missing weight documentation in each group.

Results

During the observation period, five pharmacists reviewed medications for 650 pediatric patients, representing 3,350 medications. Missing weight documentation was recorded for 54 patients (8.31%). A further 293 medication-related error events were identified, equivalent to 8.75 events per 100 medications reviewed. Together, these represented 347 recorded safety observations; the patient-level weight omissions were not included in the medication-related event rate.

All 347 identified problems were detected and corrected during pharmacist double-checking of handwritten medication orders and medication administration records before reaching patients. The recorded interception proportion was 100% among identified problems.

Among the 293 medication-related error events, administration-related discrepancies accounted for 171 (58.36%), prescribing-related events for 80 (27.30%), and dispensing-related events for 42 (14.33%). When the 54 patient-level weight omissions are also included in the count of all 347 safety observations, the prescribing/documentation category contains 134 observations (38.62%), compared with 171 administration-related observations (49.28%) and 42 dispensing observations (12.10%).

The two distributions describe different denominators: 293 medication-related error events versus 347 total safety observations. Neither is a patient-level error prevalence, as shown in table 1 and 2.

Table 1. overall medication review and corrected safety outcomes

Variable	Result
pediatric patients reviewed	650
medications reviewed	3,350
patients with missing weight	54 (8.31% of 650 patients)
medication-related error events	293 (8.75 per 100 medications)
total recorded safety observations	347 (54 patient-level + 293 events)
observations intercepted before patient exposure	347 (100%)
observations reaching patients	0 (0%)

note: the medication-related event rate excludes the 54 patient missing weight cases.

Table 2. distribution of recorded safety observations by medication-use phase

Medication-use phase	Observations (n)	Percentage of 347 (%)
prescribing and weight documentation	134	38.62
administration	171	49.28
dispensing	42	12.10
total	347	100.00

note: phase percentages describe the composition of 347 recorded safety observations; the prescribing/documentation row includes 54 patient-level omissions. medication-related events alone: prescribing 80/293 (27.30%), administration 171/293 (58.36%), dispensing 42/293 (14.33%).

Missing weight documentation was found in 54 of 650 patients (8.31%) and is reported separately from medication-related events. Among the 293 medication-related error events, missed administration time occurred most frequently (142; 48.46%).

Mathematical prescribing errors accounted for 55 of 293 medication-related events (18.77%), while illegible handwriting accounted for 25 (8.53%).

In the intended administration process, 18 wrong-dose discrepancies (6.14%) and 11 wrong-patient discrepancies (3.75%) were detected and corrected before administration to a patient.

Dispensing-related discrepancies included 17 copying/transcription mistakes (5.80%), 14 wrong-dose selections (4.78%), and 11 wrong-medication selections (3.75%), illustrated in table 3.

The 54 weight-documentation omissions were assessed per patient, whereas the other eight error types were assessed as medication-related events. All reported administration-related discrepancies were intercepted before reaching patients.

Table 3. missing-weight documentation and medication-related error types

Medication related error type	**Phase**	**Events (n)**	**Percentage of 293 (%)**
missing patient weight (54/650; 8.31% of patients)	patient-level documentation	54	not applicable
missed administration time	administration	142	48.46
mathematical error	prescribing	55	18.77
illegible handwriting	prescribing	25	8.53
wrong dose	administration	18	6.14
copying/transcription mistake	dispensing	17	5.80
wrong dose	dispensing	14	4.78
wrong medication	dispensing	11	3.75
wrong patient	administration	11	3.75
total medication-related events (excludes 54 weight omissions)		293	100.00

note: missing weight uses 650 patients as the denominator; percentages for all other rows use 293 medication-related events. the 54 weight omissions are not part of the 293-event total.

The five pharmacist/ward groups reviewed 68, 32, 100, 250, and 200 patients, respectively, comprising 272, 128, 700, 1,250, and 1,000 medications.

The original group-specific error totals were calculated using the incorrect missing-weight count of 154. The corrected overall missing-weight count is 54, but its distribution among the five pharmacist/ward groups was not provided. Consequently, corrected error counts and rates for individual groups cannot be calculated reliably from the available aggregate data, table 4.

Table 4. medication-review volume by pharmacist/ward group

Pharmacist/ward group	Patients, n	Medications reviewed, n	Corrected event count, n	Events per 100 medications
group 1	68	272	not available	not available
group 2	32	128	not available	not available
group 3	100	700	not available	not available
group 4	250	1,250	not available	not available
group 5	200	1,000	not available	not available
total	650	3,350	293 medication-related events	8.75

note: corrected event counts by group require the distribution of the 54 distinct missing-weight cases across groups; original subgroup error counts and p values were based on the superseded count of 154 and have been withdrawn.

Group review volumes describe different ward workloads and should not be interpreted as differences in pharmacists' individual performance. The fig (1).

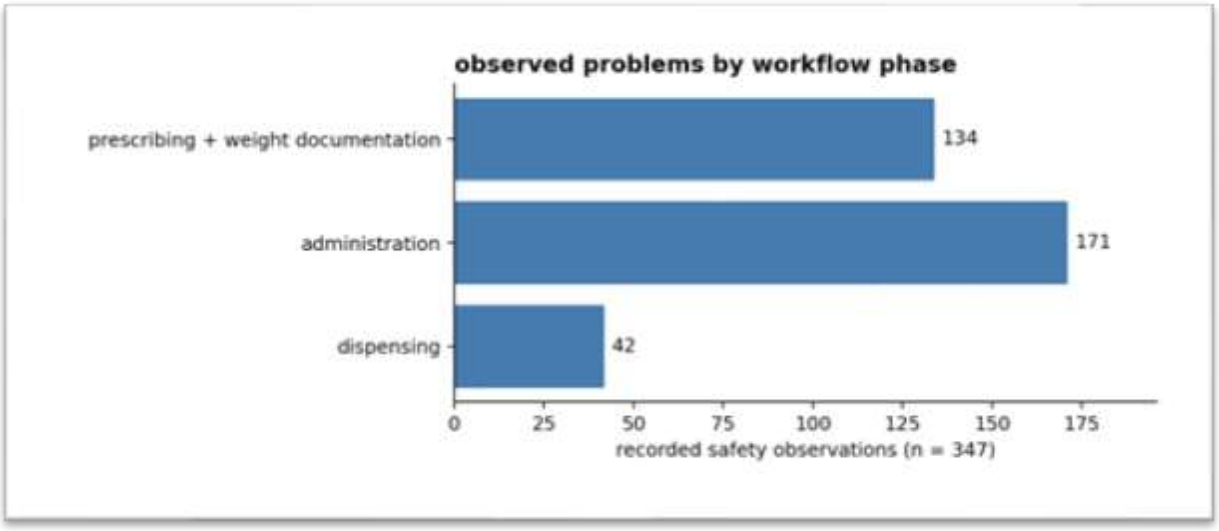

Figure1. Distribution of errors number based on workflow.

Discussion

The study documented 54 cases of missing weight among 650 pediatric patients (8.31%) and 293 other medication-related error events among 3,350 medications reviewed (8.75 events per 100 medications). Among medication-related events, administration-related discrepancies accounted for 171 (58.36%), prescribing for 80 (27.30%), and dispensing for 42 (14.33%). The 54 patient-level documentation problems should not be included in a medication-based error rate. Pharmacist double-checking intercepted all 347 recorded problems before patient exposure. Differences between studies should be interpreted cautiously because error definitions and denominators vary [6,11].

Missing patient weight was documented in 54 of the 650 children examined (8.31%). Because body weight is needed for many pediatric dose calculations, an absent or undocumented weight can compromise prescribing and checking of weight-based doses. This was a patient-level

documentation problem, not 54 separately confirmed medication-dose errors. Recent pediatric literature identifies weight-based calculations as a common source of risk [6,11]. Patient weight should be recorded in kilograms only, verified when clinically appropriate, and clearly displayed on every pediatric medication-order sheet. In a paper-based hospital, a practical low-cost intervention would be a standardized prescription form containing a mandatory patient-weight field, with orders considered incomplete when weight is absent for medications requiring weight-based dosing. Pharmacists should verify the documented weight before approving such prescriptions. In hospitals able to introduce electronic systems, computerized physician order entry (CPOE) combined with pediatric clinical decision support can automatically use weight to calculate or check doses and generate alerts for potentially inappropriate doses [8,11].

Missed administration time was the most common medication-related error identified during pharmacist checking, with 142 of 293 events (48.46%). These were detected before reaching the patient, so the study does not show that these doses were actually omitted or administered late. Unclear scheduling and manual chart communication can nevertheless create opportunities for clinically important timing errors [11]. A standardized medication administration schedule should be established within each ward, with clearly documented administration times rather than ambiguous frequency instructions alone. A medication administration record should be checked at each nursing shift, and missed or delayed doses should be documented and reviewed. Where resources allow, electronic medication administration records with reminders and barcode-assisted medication administration may provide additional safeguards. However, barcode systems should not be considered sufficient alone because recent evidence suggests that their effect differs according to the type of administration error, and they may not consistently eliminate wrong-time errors [12].

Mathematical prescribing errors accounted for 55 of 293 medication-related events (18.77%). Pediatric prescribing often requires calculations involving body weight, concentration, dose interval, total daily dose, or infusion rate; manual calculation increases opportunities for numerical and decimal-point mistakes. A recent systematic review identified pediatric dosing errors as a frequent prescribing problem [6]. Pediatric dose calculations should be supported by standardized dosing references, calculation tools, and independent verification for high-risk medicines. Pre-calculated dosing charts may be useful for commonly prescribed medications, provided the patient's actual weight and clinical condition are still considered. The strongest system-level approach is CPOE combined with pediatric clinical decision support, which can compare the entered dose with weight-based recommendations and predefined dose limits. A 2024 systematic review found that appropriately designed CPOE/CDS systems can reduce pediatric dose errors, although system design and alert quality remain important [8].

Illegible handwriting accounted for 25 of 293 medication-related events (8.53%). Although fewer than timing or calculation errors, ambiguous written drug names, doses, and instructions may be misinterpreted in a paper-based workflow. A recent hospital comparison reported reductions in prescribing errors after computerized ordering was introduced [4]. The most effective long-term strategy is replacement of handwritten orders with electronic prescribing/CPOE. Where immediate implementation is not feasible, standardized preprinted medication-order sheets should be used, and prescribers should write drug names, doses, units, routes, frequencies, and administration times clearly without non-standard abbreviations. Pharmacists and nurses should never guess an unclear prescription; an illegible order should be clarified with the prescriber before dispensing or administration.

Wrong-dose administration discrepancies accounted for 18 of 293 medication-related events (6.14%). These represented planned or charted doses identified as wrong and corrected during double-checking; none was given to the child. Pediatric patients may be particularly vulnerable to dose deviations because small numerical differences can represent substantial dose changes [6,11]. The prescribed dose should be checked against the child's current weight, medication concentration, and recommended pediatric dose before administration. Independent double-checking is particularly appropriate for high-alert medicines and complex calculations. For

intravenous drugs, standardized concentrations and smart infusion pumps with dose-error reduction systems provide additional safeguards. In a pediatric hospital study, implementation of smart-pump interoperability significantly reduced the frequency and severity of infusion-related errors and reduced high-risk overrides [13].

Copying/transcription mistakes accounted for 17 of 293 medication-related events (5.80%) and were detected during dispensing review. Re-entering or copying a paper order can introduce omission or distortion of medication instructions; in this study the identified discrepancies were corrected before patient exposure. Unnecessary transcription steps should be minimized. Where paper systems remain in use, the original medication order should be available to the pharmacist for verification, and manually copied information should be independently checked against the original order. In the longer term, an integrated electronic medication system can allow a single validated medication order to be transmitted through prescribing, pharmacy verification, dispensing, and administration without repeated manual transcription. Electronic prescribing should nevertheless retain pharmacist verification because electronic systems can introduce different error types if poorly configured [4,8].

Wrong-dose dispensing discrepancies accounted for 14 of 293 medication-related events (4.78%). The selected or prepared dose was corrected before the medicine reached the patient. Errors of drug strength, concentration, quantity, or dose selection warrant systematic pharmacy verification [14]. Dispensing should involve verification of the medication against the original prescription, including drug name, strength, dosage form, calculated dose, and patient information. High-risk pediatric preparations should receive an independent final check before leaving the pharmacy. Unit-dose dispensing, where feasible, can reduce manual handling and preparation steps. A 2026 systematic review reported reductions in medication errors when automated unit-dose systems were incorporated into hospital medication workflows, particularly when combined with barcode technology [15].

Wrong-medication dispensing discrepancies were identified in 11 of 293 medication-related events (3.75%). The erroneous medication selection was intercepted before the child received the product. Similar names, packaging, or incomplete written orders can create opportunities for selection errors. A systematic final dispensing check should compare the selected product directly with the original medication order. Pharmacy storage should also be organized to reduce selection errors, especially where medication packages or names may be easily confused. Barcode verification and unit-dose systems can add an electronic check between the prescribed drug and the selected product. Automated unit-dose systems combined with barcode scanning have been associated with reductions in medication handling and medication errors [15].

Wrong-patient administration discrepancies accounted for 11 of 293 medication-related events (3.75%). The incorrect patient assignment was recognized during double-checking before administration; no child received medication intended for another patient. Checking patient identity immediately before administration remains a key safeguard. At least two independent patient identifiers should be verified immediately before medication administration, such as the patient's full name together with a hospital identification number or date of birth, according to institutional policy. When available, bedside barcode medication administration provides an additional check linking the patient, medication, and medication order. A recent systematic review found weak-to-moderate evidence that barcode-assisted medication administration can reduce some categories of medication administration errors, although the technology does not eliminate all errors and requires correct use without workflow shortcuts [12].

The five pharmacists reviewed different numbers of patients and medications, but corrected error counts for each pharmacist/ward group were not available after revising missing-weight observations from 154 to 54. Therefore, no corrected ward-specific error rates or between-group P values can be reported. The earlier analysis based on the superseded totals should not be interpreted as a finding of this corrected study. Variations in medication-error detection may reflect ward case mix and workflow [6]. Medication-error rates should therefore be monitored by ward and normalized to medication exposure, for example as errors per 100 medication orders or

medications reviewed. Regular medication-safety audits can identify wards or stages of the workflow requiring targeted intervention. The purpose of such monitoring should be system improvement rather than individual blame.

All 347 recorded safety problems were detected and corrected before reaching patients, corresponding to 100% interception among identified problems. This included correcting potential dose, patient-identification, and administration-time discrepancies during pharmacist double-checking of handwritten orders and administration charts. This does not establish that every error occurring in the hospital was detected or that the system was error-free. Pharmacist review should remain an integral part of pediatric medication management, particularly for weight-based doses, unclear prescriptions, incomplete orders, and high-risk medications. However, pharmacist review should function as one component of a multilayered medication-safety system, rather than being the only safeguard. Recent reviews recommend combining clinical pharmacist involvement with standardized prescribing, pediatric decision support, barcode systems, electronic prescribing, smart pumps, staff education, and continuous audit [9,11].

The pattern of observed problems highlights several vulnerabilities in a handwritten medication workflow, including missing patient weight, manual calculations, ambiguous handwriting, transcription, and administration-chart discrepancies. Standardized forms with mandatory patient-weight fields, clear dose and administration-time documentation, pharmacist double-checking, and structured administration records are practical safeguards. Electronic prescribing with pediatric decision support, barcode verification, and infusion technologies may provide further safeguards where feasible [4,8,11-13].

This study has several limitations that should be considered when interpreting the findings. First, it was conducted in a single children's hospital and involved only five pharmacists, which may limit the generalizability of the results to other healthcare settings. Second, the observation period was relatively short and may not reflect seasonal or long-term variations in medication-use practices. Third, medication errors were identified through pharmacist observation and double-checking, so some unrecognized errors may have been missed. Fourth, differences among hospital wards, patient complexity, and medication workload were not fully adjusted for. Finally, because all detected errors were corrected before reaching patients, the study could not assess the clinical severity or actual consequences of medication errors.

Conclusion and Recommendations

The present study demonstrates that medication errors remain an important safety concern within a handwritten, paper-based medication workflow in a pediatric hospital. Errors occurred at different stages of medication use, particularly during prescribing and administration. Missing patient weight, missed administration time, mathematical errors, and illegible handwriting were among the important problems identified. However, all detected errors were recognized and corrected through pharmacist double-checking before reaching the patients, emphasizing the important role of pharmacists as a safety barrier. The findings also indicate that medication safety should not depend solely on individual vigilance but should be supported by a structured and standardized medication-management system.

Medication safety in pediatric hospitals can be improved by introducing standardized prescription and medication-administration forms with mandatory documentation of patient weight, drug dose, route, frequency, and administration time. Pediatric dose calculations should be independently double-checked, particularly for high-risk and weight-based medications. Pharmacist review should remain an essential step before medication dispensing and administration. Regular staff education and medication-safety audits should be conducted to identify recurring errors and improve practice. Clear handwriting and avoidance of non-standard abbreviations should be emphasized while paper-based systems remain in use. In the longer term, implementation of electronic prescribing with pediatric clinical decision support, barcode-assisted medication administration, and smart infusion systems should be considered to reduce dependence on manual

transcription and calculation.

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