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Original Article

Compliance of Nurses with Medication Administration Protocols and its Effect on Adverse Drug Events in Children Hospital, Multan

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ABSTRACT

Background: Medication administration errors remain a major threat to pediatric patient safety because children require weight-based dosing, age-specific adjustments, and close monitoring for medication-related harm. Nurses serve as the final safety checkpoint before medication reaches the patient, making compliance with medication administration protocols essential in pediatric care. Objective: To assess nurse compliance with medication administration protocols and examine its association with medication administration errors and adverse drug events in a pediatric hospital in Multan, Pakistan. Methods: A descriptive correlational observational study was conducted among 78 registered nurses working in pediatric medical, surgical, and intensive care units. Compliance was assessed through 234 observed medication administration episodes using a structured checklist covering patient identification, dose verification, right-time administration, documentation, and independent double-checking of high-alert medications. Medication-related events were classified by type and severity. Descriptive statistics, correlation analysis, regression analysis, and training-based compliance comparison were performed. Results: Overall protocol compliance was 67.4% ± 8.2%. Compliance was highest for patient identification (82.1%) and lowest for high-alert medication double-checking (43.6%). A total of 124 medication-related events were documented, most commonly dosing errors (34.7%), omitted doses (22.6%), and wrong-time administration (17.7%). Overall compliance showed a strong inverse association with medication-related event rates ($r = -0.72$, $p < 0.001$), and trained nurses demonstrated significantly higher compliance than untrained nurses (73.8% vs. 63.5%, $p < 0.001$). Conclusion: Nurse compliance with medication administration protocols was suboptimal and was strongly associated with medication-related event rates. Targeted interventions focusing on high-alert medication double-checking, documentation, dose verification, and regular safety training are recommended. Keywords: Medication errors; medication administration; pediatric nursing; adverse drug events; patient safety; protocol compliance; Pakistan.

INTRODUCTION

Medication administration is one of the most critical responsibilities in pediatric nursing practice because it represents the final clinical checkpoint before a prescribed drug reaches the patient. Although safe medication practice is fundamental to quality care, medication administration errors remain a persistent source of preventable harm in hospital settings. The risk is particularly heightened in children because pediatric pharmacotherapy commonly requires age-specific and weight-based dose calculations, dilution of medicines, adjustment of administration routes, and close monitoring of physiological responses. These complexities increase the probability that errors in dose calculation, timing, route selection, patient identification, or documentation may reach the child before detection. Pediatric patients are also less able than adults to recognize or communicate medication-related problems, making protocol-based nursing safeguards especially important in preventing avoidable medication-related harm (1,2).

Medication safety in pediatric care has therefore become a major global patient-safety priority. Medication errors in children may occur at prescribing, dispensing, preparation, administration, or monitoring stages, but the administration phase is uniquely important because nurses are directly responsible for verifying the right patient, right medication, right dose, right route, right time, and accurate documentation before and after administration. In pediatric wards and intensive care units, errors involving high-alert medicines, intravenous preparations, infusions, and omitted or delayed doses may have serious clinical consequences. International evidence has shown that medication errors constitute a substantial proportion of reported pediatric safety events, with dosing errors, wrong-time administration, omitted doses, and documentation-related failures among the commonly reported patterns (2,3). Compliance with medication administration protocols is therefore not merely a procedural requirement; it is a direct nursing safety behavior that may reduce the probability that medication errors reach patients or progress to adverse drug events.

The concept of medication safety requires clear distinction between medication errors, near misses, and adverse drug events. A medication error refers to a preventable event that may cause or lead to inappropriate medication use or patient harm, whether or not harm actually occurs. A near miss refers to an error intercepted before reaching the patient, whereas an adverse drug event refers to patient injury or clinical harm associated with medication use. In routine clinical reporting, these categories are sometimes combined, but for research purposes they should be differentiated because wrong-time administration, omitted doses, documentation errors, and intercepted events do not necessarily represent harmful adverse drug events. This distinction is particularly relevant in pediatric nursing research because error frequency, severity, and clinical consequences may vary substantially across medication type, unit acuity, route of administration, and patient vulnerability.

Compliance with standardized medication administration protocols has been repeatedly identified as a modifiable safety factor. The traditional “rights” of medication administration, together with independent double-checking of high-alert medications, timely documentation, and verification against medication administration records, provide a structured framework for reducing preventable errors. However, compliance is often inconsistent in busy clinical environments where nurses work under time pressure, high patient load, frequent interruptions, and limited technological support. Recent quality-improvement work in pediatric settings has shown that targeted interventions such as structured training, checklists, visual cues, and audit-feedback cycles can improve double-check compliance and reduce medication error reports (4). Similarly, nurse-led medication safety bundles in pediatric intensive care have demonstrated that context-appropriate, low-cost interventions can improve medication-use practices and reduce administration-related errors (5,6).

In low- and middle-income healthcare settings, including Pakistan, pediatric medication safety is further complicated by resource constraints, high patient-to-nurse ratios, limited availability of barcode medication administration systems, variable reporting cultures, and inconsistent implementation of formal medication safety training. Nurses in such settings frequently function as the most immediate safeguard against preventable medication-related harm. Despite this, local evidence linking directly observed nursing compliance with medication administration protocols to verified medication administration errors and adverse drug events remains limited. Most available literature focuses on general medication-error prevalence, prescribing issues, or international quality-improvement experiences, while fewer studies provide institution-specific evidence from Pakistani pediatric hospitals using direct observation and structured severity classification.

This study was therefore designed to address this local evidence gap by assessing compliance of nurses with medication administration protocols and examining its association with medication administration errors and adverse drug events in a tertiary pediatric hospital in Multan, Pakistan. Using nurses directly involved in pediatric medication administration as the population, observed medication administration protocol compliance as the exposure, and medication administration errors/adverse drug events as the

outcome, the study sought to determine whether lower protocol compliance was associated with higher medication-related event rates. The objective of the study was to assess the level of nurse compliance with key medication administration safety protocols and to examine the association between overall and domain-specific compliance scores and the frequency and severity of medication administration errors and adverse drug events in hospitalized pediatric patients.

MATERIAL AND METHODS

A descriptive correlational observational study was conducted to assess nurse compliance with medication administration protocols and to examine its association with medication administration errors and adverse drug events among hospitalized pediatric patients. This design was selected because the study aimed to measure naturally occurring clinical practice without manipulating exposure or introducing an intervention. The study was conducted over a six-month period from January to June 2025 in pediatric medical wards, pediatric surgical wards, and the pediatric intensive care unit of a tertiary pediatric hospital in Multan, Pakistan. These units were selected because nurses working in these areas routinely administer oral, injectable, intravenous, and high-alert medications to children with varying levels of clinical acuity.

The study population comprised registered nurses directly involved in medication preparation and administration in the selected pediatric units. Nurses were eligible for inclusion if they held a valid nursing license, had at least six months of experience in their current unit, were actively assigned to medication administration duties during the data-collection period, and provided written informed consent. Nurses who were on extended leave, working exclusively in administrative roles, undergoing orientation without independent medication administration responsibility, or unwilling to participate were excluded. Of the eligible nursing staff, 78 nurses fulfilled the inclusion criteria and participated in the study, representing approximately 85% of eligible nurses in the selected units. This near-complete participation improved representativeness of nursing practice within the study setting.

The sample size was based on the available eligible nursing population during the study period and was considered adequate for detecting a moderate-to-strong correlation between protocol compliance and medication-related event rates at a conventional alpha level of 0.05 and statistical power of 80%. Because the study included most eligible nurses in the selected units, the final sample reflected a pragmatic census-based approach rather than probability sampling. Each participating nurse was assigned a unique study code to protect identity and to permit linkage between observed compliance data and medication-related event data without using personal identifiers in the analysis.

Data were collected using three instruments: a medication administration compliance checklist, an adverse drug event and medication-error reporting form, and a demographic and professional characteristics form. The medication administration compliance checklist assessed five core domains of safe medication administration: patient identification using two identifiers, verification of the right dose against the medication administration record, administration at the prescribed time, accurate documentation after administration, and independent double-checking for high-alert medications. Each checklist item was scored as compliant or non-compliant. Domain-level compliance percentages were calculated by dividing the number of compliant actions by the total applicable items in that domain and multiplying by 100. The overall compliance score was calculated as the weighted percentage of all compliant checklist items across applicable domains for each nurse. The checklist was pilot-tested before the main study on nurses outside the final analytic sample, and its internal consistency was acceptable, with a Cronbach's alpha of 0.87.

The medication-error and adverse drug event reporting form captured medication-related events observed or reported during the six-month study period. Events were categorized by type, including dosing error, omitted dose, wrong-time administration, wrong medication, wrong route, wrong patient, documentation error, and other medication-related events. Severity was classified using the National

Coordinating Council for Medication Error Reporting and Prevention Index categories. For analytic clarity, near misses and errors that did not reach the patient were treated as medication errors, while events that reached the patient and resulted in clinical harm or required intervention were treated as adverse drug events. This distinction was used to reduce outcome misclassification and to avoid interpreting all medication errors as harmful adverse drug events.

Demographic and professional characteristics collected from participants included age, gender, educational qualification, assigned unit, total nursing experience, pediatric nursing experience, and attendance at formal medication safety training within the preceding two years. Medication safety training was treated as a key explanatory variable because training may influence compliance behavior and could confound the relationship between compliance and medication-related events. Unit assignment, pediatric experience, and total nursing experience were also considered clinically relevant variables because medication complexity and patient acuity may differ between wards and the pediatric intensive care unit.

Direct observations of medication administration were conducted by four trained nurse research assistants who were not employed in the study units. Each participating nurse was observed during three medication administration episodes selected across different shifts, including morning, evening, and night duties where feasible. Observers were trained before data collection to ensure consistent interpretation of checklist items and event definitions. Observations were conducted unobtrusively to minimize disruption of clinical care and reduce observer influence on routine practice. To address observer bias, the research assistants used standardized checklist criteria, and ambiguous observations were reviewed by the principal investigator before final coding. Where possible, medication-related event data were triangulated from direct observation, incident reports, medication-error reporting records, and quality-improvement documentation.

Medication-related events were reviewed before inclusion in the final dataset to avoid duplicate counting. When the same event appeared in more than one source, it was counted once after verification. Event attribution was based on the medication administration episode, nursing assignment record, and available incident documentation. For rate-based analysis, medication-related events were expressed per 1000 medication doses administered when denominator data were available from medication administration records. Where individual nurse-level dose denominators were incomplete, the analysis was restricted to verified events linked to observed or documented medication administrations, and interpretation was limited to association rather than causation.

The primary exposure variable was overall medication administration protocol compliance percentage. Secondary exposure variables were domain-specific compliance percentages for patient identification, right-dose verification, right-time administration, documentation, and independent double-checking of high-alert medications. The primary outcome was the medication-related event rate, defined as the number of medication administration errors and adverse drug events per 1000 medication doses administered. Secondary outcomes included event type and severity category. The main hypothesis was that higher overall and domain-specific compliance scores would be associated with lower medication-related event rates.

Several measures were used to reduce bias and improve data integrity. Direct observation was used rather than self-report to reduce social desirability bias. Observers were external to the study units to minimize professional hierarchy effects. Multiple data sources were used to improve event capture and reduce underreporting. Duplicate event entries were removed after review. Standardized operational definitions were applied to all compliance domains and medication-related event categories. Data were entered using coded identifiers, checked for completeness, and reviewed for logical inconsistencies before analysis. Any missing demographic or checklist values were assessed before analysis; complete-case analysis was used for variables with minimal missingness, while variables with substantial missingness were not included in adjusted models.

Data were analyzed using SPSS version 26.0. Descriptive statistics were calculated for demographic characteristics, professional variables, compliance scores, and medication-related event categories. Frequencies and percentages were used for categorical variables, while means, standard deviations, ranges, and 95% confidence intervals were used for continuous variables where appropriate. Overall and domain-specific compliance scores were summarized at nurse level. Medication-related events were summarized by type and severity, and event rates were calculated per 1000 medication doses where denominator data were available. The association between overall compliance and medication-related event rate was assessed using Pearson correlation when assumptions of linearity and approximate normality were met; otherwise, Spearman rank correlation was planned as a sensitivity analysis. Simple linear regression was used to estimate the unadjusted relationship between compliance score and event rate. Multivariable regression was planned to adjust for medication safety training, total nursing experience, pediatric nursing experience, and unit assignment where model assumptions and sample size permitted. Independent-samples t-test was used to compare compliance scores between nurses who had received medication safety training and those who had not. Statistical significance was set at $p < 0.05$, and effect estimates were reported with 95% confidence intervals where applicable. Ethical approval was obtained from the institutional review board of the participating hospital before data collection. Administrative permission was obtained from hospital leadership and the nursing department. All participants provided written informed consent after being informed about the study purpose, observation procedures, voluntary participation, confidentiality protections, and their right to withdraw without penalty. No patient-identifying information was included in the analytic dataset. Nurse identities were replaced with coded identifiers, and all electronic data were stored in password-protected files accessible only to the research team. The study was conducted as an observational assessment of medication administration practice and did not interfere with prescribed treatment or routine nursing care.

RESULTS

A total of 78 registered nurses working in pediatric medical, surgical, and intensive care units were included in the analysis. The majority of participants were female (n = 56, 71.8%), while 22 (28.2%) were male. The mean age was 31.4 ± 5.7 years (range 23–49). Regarding educational qualification, 35 nurses (44.9%) held a Bachelor of Science in Nursing, 29 (37.2%) held a diploma, and 14 (17.9%) held a Master of Science in Nursing or higher. Most participants were assigned to pediatric medical wards (n = 41, 52.6%), followed by pediatric surgical wards (n = 22, 28.2%) and the pediatric intensive care unit (n = 15, 19.2%). Mean total nursing experience was 7.2 ± 4.3 years, and mean pediatric nursing experience was 4.8 ± 3.1 years. Only 29 nurses (37.2%) had received formal medication safety training during the preceding two years, whereas 49 (62.8%) had not.

Table 1. Demographic and Professional Characteristics of Nurse Participants (N = 78)

Characteristic	Category	n (%)
Gender	Male	22 (28.2)
	Female	56 (71.8)
Education	Diploma in Nursing	29 (37.2)
	Bachelor of Science in Nursing	35 (44.9)
	Master of Science in Nursing or higher	14 (17.9)
Unit assignment	Pediatric Medical Ward	41 (52.6)
	Pediatric Surgical Ward	22 (28.2)
	Pediatric Intensive Care Unit	15 (19.2)
Medication safety training (past 2 years)	Yes	29 (37.2)
	No	49 (62.8)

Continuous variables (mean ± SD, range): Age 31.4 ± 5.7 years (23–49); total nursing experience 7.2 ± 4.3 years (1–21); pediatric nursing experience 4.8 ± 3.1 years (0.5–16).

Across 234 observed medication administration episodes, overall mean compliance with medication administration protocols was 67.4% ± 8.2% (range 48–89% at the nurse level). Compliance was highest

for patient identification using two identifiers (82.1% ± 6.4%; 95% CI 80.7–83.5) and lowest for independent double-checking of high-alert medications (43.6% ± 12.3%; 95% CI 40.8–46.4), indicating that more than half of required double-check practices were not completed according to protocol. The largest safety gap was therefore in independent double-checking, with a 56.4 percentage-point shortfall from full compliance.

Table 2. Nurse Compliance with Medication Administration Protocol Domains (78 Nurses; 234 Observations)

Compliance Domain	Mean % ± SD	95% CI	Range (%)	Gap from 100%
Patient identification (two identifiers)	82.1 ± 6.4	80.7–83.5	67–100	17.9
Verification of right dose	71.3 ± 7.8	69.5–73.1	50–92	28.7
Administration at prescribed time	64.7 ± 9.1	62.6–66.8	33–83	35.3
Accurate post-administration documentation	58.9 ± 10.2	56.6–61.2	42–75	41.1
Independent double-check (high-alert meds)	43.6 ± 12.3	40.8–46.4	17–67	56.4
Overall protocol compliance	67.4 ± 8.2	65.6–69.2	48–89	32.6

Medication safety training was significantly associated with higher protocol compliance. Trained nurses had a mean compliance score of 73.8% ± 6.9%, compared with 63.5% ± 7.4% among untrained nurses. The mean difference of 10.3 percentage points (95% CI 6.8–13.8) was statistically significant, $t(76) = 5.91$, $p < 0.001$, with a large effect size (Cohen's $d = 1.43$).

Table 3. Comparison of Overall Compliance by Medication Safety Training Status

Training Status	n	Mean % ± SD
Training received	29	73.8 ± 6.9
No training	49	63.5 ± 7.4
Difference	—	10.3 (95% CI 6.8–13.8)

$t(76) = 5.91$, $p < 0.001$; Cohen's $d = 1.43$.

During the six-month study period, 124 medication-related events were documented. Dosing errors were most frequent (n = 43, 34.7%), followed by omitted doses (n = 28, 22.6%) and wrong-time administration (n = 22, 17.7%). Less frequent categories included wrong medication (n = 10, 8.1%), documentation errors (n = 9, 7.3%), wrong route (n = 5, 4.0%), wrong patient (n = 4, 3.2%), and other events (n = 3, 2.4%). By severity, 34 events (27.4%) were Category B (did not reach the patient), 68 (54.8%) Category C (reached the patient without harm), 16 (12.9%) Category E (requiring intervention), and 6 (4.8%) Category F (temporary harm requiring or prolonging hospitalization). No Category G, H, or I events were reported.

Table 4. Medication-Related Events by Type and Severity Category (N = 124 Events)

Event Type	Total n (%)	Cat B	Cat C	Cat E	Cat F
Dosing error	43 (34.7)	0	31	10	2
Omitted dose	28 (22.6)	15	13	0	0
Wrong-time administration	22 (17.7)	10	12	0	0
Wrong medication	10 (8.1)	0	5	3	2
Documentation error	9 (7.3)	9	0	0	0
Wrong route	5 (4.0)	0	2	2	1
Wrong patient	4 (3.2)	0	2	1	1
Other	3 (2.4)	0	3	0	0
Total	124 (100)	34	68	16	6

Cells show event counts. Category B = did not reach patient; C = reached patient, no harm; E = intervention required; F = temporary harm requiring/prolonging hospitalization.

The severity distribution showed that most events either did not reach the patient or reached the patient without harm. However, 22 events (17.7%) were associated with temporary harm (Categories E and F combined). Dosing errors accounted for the largest absolute number of harm-related events (12 of 22). Although less frequent in absolute terms, wrong medication, wrong-route, and wrong-patient errors carried higher proportional severity, with 5 of 10, 3 of 5, and 2 of 4 events respectively classified as Category E or F.

Overall protocol compliance demonstrated a strong inverse association with medication-related event rates (Pearson r = –0.72, 95% CI –0.81 to –0.59, p < 0.001), indicating that higher compliance was associated with fewer events. In simple linear regression, compliance significantly predicted event rate, $F(1,76) = 79.43$, $p < 0.001$, explaining 51% of the variance ($R^2 = 0.51$). The unstandardized coefficient was –0.18 (95% CI –0.22 to –0.14), indicating that each 1 percentage-point increase in compliance was associated with an estimated reduction of 0.18 events per 1000 administrations; a 10-point increase would correspond to an estimated reduction of 1.8 events per 1000 administrations, assuming a linear association. Domain-specific analysis showed that independent double-checking for high-alert medications had the strongest inverse association with events (r = –0.68), followed by accurate documentation (r = –0.54), right-dose verification (r = –0.49), and patient identification (r = –0.31). These findings suggest that while all domains contributed to medication safety, high-alert double-checking, documentation, and dose verification were the most clinically relevant.

Table 5. Association Between Protocol Compliance and Medication-Related Event Rates

Predictor	Estimate	95% CI	p-value
Overall compliance ↔ event rate (correlation)	r = –0.72	–0.81 to –0.59	<0.001
Overall compliance → event rate (regression)	B = –0.18 †	–0.22 to –0.14	<0.001
Independent double-check compliance	r = –0.68	–0.78 to –0.54	<0.001
Accurate documentation compliance	r = –0.54	–0.68 to –0.36	<0.001
Right-dose verification compliance	r = –0.49	–0.64 to –0.30	<0.001
Patient identification compliance	r = –0.31	–0.50 to –0.09	0.006

† Events per 1000 administrations per 1% compliance increase; regression model $R^2 = 0.51$, $F(1,76) = 79.43$.

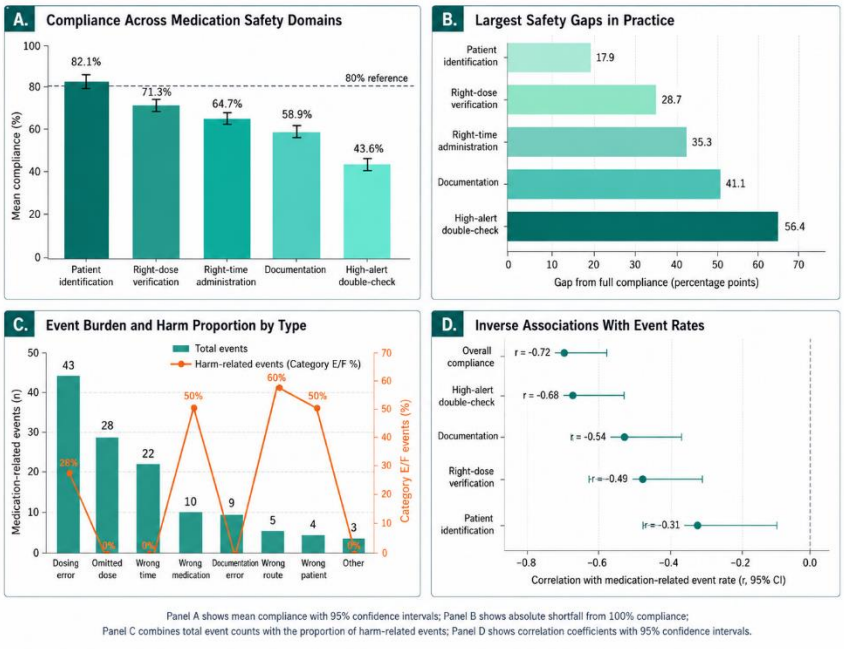

Figure 1. Nurse Compliance with Medication Administration Protocols and Medication-Related Events.

The panelled figure summarizes compliance patterns, safety gaps, medication-related event burden, and compliance–event associations among pediatric nurses. Panel A shows that mean protocol compliance was highest for patient identification (82.1%) and progressively lower for right-dose verification (71.3%), right-time administration (64.7%), documentation (58.9%), and high-alert medication double-checking (43.6%), with only patient identification exceeding the 80% reference threshold. Panel B demonstrates that the largest compliance gap was observed for high-alert medication double-checking, with a 56.4 percentage-point shortfall from full compliance, followed by documentation (41.1 percentage points) and right-time administration (35.3 percentage points). Panel C shows that dosing errors were the most frequent medication-related event (n = 43), followed by omitted doses (n = 28) and wrong-time administration (n = 22), while wrong-route, wrong-medication, and wrong-patient errors showed higher

proportional harm-related severity, with Category E/F events reaching 60%, 50%, and 50%, respectively. Panel D demonstrates inverse correlations between compliance and medication-related event rates, with the strongest association observed for overall compliance (r = -0.72), followed by high-alert medication double-checking (r = -0.68), documentation (r = -0.54), right-dose verification (r = -0.49), and patient identification (r = -0.31), indicating that stronger adherence to medication administration protocols was associated with lower medication-related event rates.

Overall, medication administration protocol compliance was suboptimal, particularly for independent double-checking of high-alert medications and timely documentation. Medication safety training was strongly associated with better compliance, and higher compliance was consistently associated with fewer medication-related events. The strongest safety signal was for high-alert medication double-checking, which had both the lowest compliance rate and the strongest inverse relationship with event rates. These findings support targeted quality-improvement strategies focused on high-alert medication verification, documentation accuracy, and regular medication safety training.

DISCUSSION

The present study examined nurse compliance with medication administration protocols and its association with medication administration errors and adverse drug events in a pediatric hospital setting in Multan. The findings demonstrate that overall protocol compliance was suboptimal, with a mean compliance rate of 67.4%, and that adherence varied substantially across safety domains. Compliance was highest for patient identification using two identifiers and lowest for independent double-checking of high-alert medications. This pattern is clinically important because pediatric medication administration involves weight-based dosing, age-specific pharmacological considerations, dilution requirements, and heightened vulnerability to dosing and route-related errors (1). The results therefore indicate that although basic identity verification practices were relatively better established, more complex safety behaviors requiring time, coordination, and second-person verification remained weak points in routine nursing practice.

The low compliance with independent double-checking for high-alert medications is one of the most important findings of this study. High-alert medications are associated with a greater potential for serious patient harm when errors occur, and pediatric settings intensify this risk because small dose deviations may produce clinically meaningful consequences (2). In this study, independent double-checking showed the lowest compliance rate at 43.6% and the strongest domain-specific inverse correlation with medication-related event rates. This suggests that double-checking practices should be prioritized in local medication safety interventions, particularly for intravenous medications, infusions, opioids, insulin, concentrated electrolytes, and other medicines requiring dose calculation or dilution (2). It should be acknowledged, however, that the evidence on double-checking is mixed; direct observational work in pediatric inpatients has reported that mandated or primed double-checking does not consistently confer measurable reductions in error rate or severity compared with single-checking, underscoring that double-checks deliver benefit only when performed as genuinely independent verifications rather than as a perfunctory routine (3). Similar quality-improvement work in pediatric settings has shown that structured double-check protocols, visual reminders, standardized checklists, and regular audit-feedback mechanisms can substantially improve compliance and reduce medication error reports (4).

The distribution of medication-related events further supports the need for targeted safety interventions. Dosing errors were the most frequent event type, followed by omitted doses and wrong-time administration. This pattern is consistent with the known complexity of pediatric medication administration, where dose calculations depend on weight, formulation, concentration, and route of administration (1). Although wrong-medication, wrong-route, and wrong-patient events occurred less frequently, they represented clinically important categories because a higher proportion of these events

were associated with temporary harm or the need for intervention. This distinction is important because medication safety improvement should not focus only on the most frequent errors but also on error categories with greater severity potential.

The observed inverse association between overall compliance and medication-related event rates provides meaningful evidence that protocol adherence is linked with safer medication administration practice. Overall compliance showed a strong negative correlation with medication-related event rates, and regression analysis indicated that higher compliance explained a substantial proportion of variability in event rates. However, because this was an observational correlational study, the findings should be interpreted as evidence of association rather than direct causation. It is likely that nurses with higher compliance scores also practiced other safety behaviors not fully measured in this study, and event rates may also have been influenced by workload, patient acuity, medication complexity, shift pattern, staffing ratios, and unit-level safety culture (5). Therefore, the results support targeted quality-improvement action but should not be interpreted as proving that compliance alone caused the observed differences in event rates.

Medication safety training was strongly associated with higher compliance. Nurses who had received medication safety training within the preceding two years had substantially higher compliance scores than those without recent training, with a large effect size. This finding suggests that structured professional development remains an important component of safe pediatric medication practice (6). Nevertheless, training alone is unlikely to produce sustained improvement unless it is reinforced through system-level supports. Regular competency assessment, medication safety huddles, unit-based reminders, standard operating procedures, and non-punitive error review processes are needed to translate training into consistent bedside practice (5). Previous pediatric medication safety initiatives have similarly shown that bundled strategies combining education, standardized documentation, structured observation, and audit-feedback can reduce medication errors more effectively than isolated educational sessions (6,7).

The findings also highlight the importance of accurate documentation as a safety behavior. Documentation compliance was only 58.9%, and documentation showed a moderate inverse correlation with medication-related event rates. Delayed or incomplete documentation may contribute to duplicated doses, omitted doses, unclear medication histories, and poor continuity of care, especially during shift changes or patient transfers (8). In pediatric wards where several medications may be scheduled at different times and doses are frequently adjusted according to clinical condition or body weight, real-time documentation is essential for safe coordination among nurses, physicians, and pharmacists. Therefore, medication safety interventions in the study setting should include immediate documentation after administration, periodic chart audits, and simplified medication administration records that reduce documentation burden while improving accuracy (7).

The relatively higher compliance with patient identification is encouraging, but the rate still fell below the ideal standard of full adherence. Patient identification errors are uncommon but potentially serious, particularly in pediatric wards where patients may be unable to verbally confirm their identity or may have similar names, shared caregivers, or frequent bed transfers (1). In this study, patient identification had the weakest correlation with medication-related event rates among the measured domains, but it remained statistically significant. This finding suggests that patient identification is a foundational safety step that should be maintained at near-universal levels even when other domains require more urgent improvement.

The study has several practical implications for pediatric nursing administration and hospital quality improvement. First, a standardized high-alert medication double-check policy should be implemented, requiring independent verification by two qualified nurses before administration (2). Second, annual medication safety training should be made mandatory for all nurses involved in pediatric medication administration, with additional simulation-based training for high-risk scenarios such as intravenous

infusions, emergency medications, and weight-based dose calculation (6). Third, a non-punitive medication-error reporting system should be strengthened so that near misses, non-harmful errors, and harmful adverse drug events are reported consistently and used for system learning rather than individual blame (5). Fourth, regular audit and feedback should be introduced to monitor compliance trends, identify recurring error patterns, and evaluate whether interventions improve practice over time (7).

The study also has limitations that must be considered when interpreting the findings. The observational assessment may have been affected by the Hawthorne effect, as nurses may have improved their practice while being observed. Although observers attempted to minimize disruption and conducted observations across shifts, the possibility of behavior modification cannot be excluded. Medication-related events may also have been underreported despite the use of multiple data sources, particularly events that did not cause visible harm (8). The study was conducted in a single hospital, which limits generalizability to other pediatric hospitals, private institutions, or lower-resource district settings. The compliance assessment was based on three observed medication administration episodes per nurse, whereas medication-related events were collected over a six-month period; therefore, the compliance score may not fully capture each nurse's usual practice over the entire study period. Finally, potential confounders such as workload, nurse-patient ratio, interruptions, patient acuity, medication class, and shift timing were not fully incorporated into the analysis.

Despite these limitations, the study provides useful local evidence on pediatric medication safety and nursing protocol compliance. Its strengths include direct observation of medication administration practice, inclusion of multiple pediatric care areas, use of structured compliance domains, and severity classification of medication-related events. The findings indicate that improving medication administration safety in pediatric hospitals requires both individual-level competency development and system-level redesign. The strongest improvement opportunities appear to be high-alert medication double-checking, real-time documentation, right-dose verification, and regular medication safety training.

CONCLUSION

Nurse compliance with medication administration protocols in the studied pediatric hospital was below the expected standard, particularly for independent double-checking of high-alert medications and accurate post-administration documentation. Medication-related events were most frequently represented by dosing errors, omitted doses, and wrong-time administration, while less frequent wrong-route, wrong-medication, and wrong-patient errors carried greater proportional clinical severity. Higher overall protocol compliance was strongly associated with lower medication-related event rates, although the observational design supports association rather than causation. Recent medication safety training was also associated with markedly better compliance, indicating the value of structured and repeated professional development. These findings support implementation of a targeted medication safety improvement program focusing on high-alert medication verification, timely documentation, dose-checking accuracy, non-punitive reporting, and routine audit-feedback mechanisms to strengthen pediatric patient safety.

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