Evaluating Pediatric Nurse Adherence to the Six Rights of Medication Administration

Tiffany M. Kidd

Edson College of Nursing and Health Innovation, Arizona State University

Author Note

Tiffany M. Kidd is a graduate student at the Edson College of Nursing and Health Innovation at Arizona State University.

I have no known conflict of interest to disclose.

Correspondence concerning this article should be addressed to Tiffany M. Kidd, Edson College of Nursing and Health Innovation, Arizona State University, 550 N. 3rd Street, Phoenix, AZ 85004, email: tmkidd1@asu.edu

Abstract

Pediatric medication errors pose significant risks to patient safety. Research suggests that mobile phones aid in scanning barcodes, issuing alerts, verifying medical details, and documenting medication administration in real-time. However, limited studies examine their impact on adherence to the six rights of medication administration, necessitating further research. This quantitative project conducted a gap analysis to assess mobile phone use and nurses' compliance with the six rights in the pediatric intensive care unit (PICU) at a free-standing children's hospital in the Southwestern U.S. A pre-intervention survey using the Medication Administration Evaluation and Feedback Tool (MAEFT) analyzed adherence rates, with findings compared to a future post-intervention study after implementing workstations on wheels (WOWs). Descriptive statistics with cross-tabulation were used to evaluate nurse-reported adherence and perceptions. The quality improvement project had an Institutional Review Board (IRB) exemption, as it involved minimal risk and no identifiable patient data. Preliminary findings indicated that mobile phone-assisted medication administration enhances compliance, particularly in dosage accuracy and patient identification. Nurses reported improved workflow efficiency and fewer distractions compared to traditional methods. The gap analysis suggested that integrating mobile phones into pediatric medication administration improves adherence rates, enhances efficiency, and ultimately strengthens patient safety.

Keywords: pediatric, medication errors, technology, healthcare, patient safety, WOW, computer, medication administration, barcode scanning

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Patient safety is a critical quality determinant throughout the care continuum. Nevertheless, extensive safety issues continue to affect the system's quality and efficiency of care. Medication errors are the most common occurrences in the healthcare system, resulting in significant side effects and adverse events. Medication errors remain a concern as healthcare strives to enhance quality and efficiency.

Background and Significance

A recent literature review identified medication errors as a complex multidimensional issue that can occur during medication handling, such as prescribing a medication, transcribing information to a medical record, and preparing the medication for dispensing, administration, and documentation. To address such complexity, comprehensive and multifaceted strategies are required (Alrabadi et al., 2021; Jinadatha et al., 2022; Kirit, 2023). Additionally, the authors emphasize the necessity of working on the efficiency gap within the healthcare system and improving staff's ability to handle ever-increasing workloads. Efficiency and effectiveness are necessary to achieve this goal. Moreover, they suggest that interoperability and easier access to patient documents, automated documentation, and efficient processes warrant consideration (Alrabadi et al., 2021; Jinadatha et al., 2022; Kirit, 2023).

Pediatrics

According to the United States Pharmacopoeia Medication Errors Reporting Program, the pediatric population is statistically at an increased risk of medication errors three times that of adults (D'Errico et al., 2022). This vulnerability underscores the need for tailored interventions and heightened vigilance in pediatric medication management. The unique physiological characteristics of children, variable dosing requirements, and communication challenges further amplify the complexity of ensuring accurate and safe medication administration in this population. In children, dosage calculations are critical due to the expansive variation in age and weight that is essential in preventing toxicity and adverse reactions (San et al., 2019). Dosage calculations use factors such as the patient's height, weight, and age to determine the exact amount of medication indicated for the patient, particularly children. This process is crucial for preventing potential toxicity or adverse reactions by ensuring an accurate amount of medication is administered (Gates et al., 2019; San et al., 2019).

The challenges in pediatric medication delivery extend beyond population-centered concerns. Issues such as understaffing, the presence of non-experienced or non-pediatric care providers, and the variability of medication delivery across healthcare organizations further compound the complexity of system care delivery, contributing to potential errors in pediatric medication management (Cifra et al., 2021; Rodziewicz & Hipskind, 2020). Scholars argue that children require a more individualistic approach to handling medications to avoid medication error problems (Cifra et al., 2021; Rodziewicz & Hipskind, 2020).

Computer Stations

Researchers and health systems increasingly use technology to mitigate medication errors and enhance care accuracy. Manias et al. (2020) report that computerized physician data entry (CPOE) is the most frequently implemented intervention used to automate the ordering and dispensing of drugs. However, due to the complex nature of drug handling phases and the increase in medication errors, CPOE may only partially solve this problem (Bante et al., 2023; Lion et al., 2021; Salar et al., 2020). Other potential alternatives include improved use of electronic medical records (EMRs) through interoperability, efficient file access, and wearable devices for assessment. (Kirit, 2023; Manias et al., 2020; Poland et al., 2023). Using barcodes facilitates accurate patient medication linkage, minimizing errors (Kirit et al., 2023; Manias et al., 2020). Technology adoption, such as CPOE, improves drug ordering efficiency but does not fully address complexities. Enhancing EMR interoperability, wearable devices, and workstations with scanners offer promising avenues to improve medication safety and efficiency. Furthermore, workstations on wheels (WOW) with scanners are gaining increasing attention (Kirit et al., 2023; Manias et al., 2020; Poland et al., 2023).

Jinadatha et al. (2022) and Poland et al. (2023) argue that a WOW computer station with a scanner would optimize nurse efficiency in documentation and allow real-time care. The authors assert that healthcare providers must use WOW computer stations to uphold the six rights associated with medication administration and provide real-time patient care through bedside scanning and automated documentation (Jinadatha et al., 2022; Poland et al., 2023). Kirit (2023) states that implementing WOW computers with scanners is anticipated to decrease the burden on healthcare systems by ensuring streamlined access to medical record information and enhanced accuracy in documentation facilitated by WOW and scanning technologies.

No Computer Stations

Time is one of the most limiting factors in pediatric units and the healthcare industry. Medication administration is often time-specific. Factors that affect the ability to meet these demands include increased need for care, heavy workloads, and staff burnout. Addressing these factors is crucial for optimizing medication administration practices by ensuring timely and safe patient-centered care delivery (Alrabadi et al., 2021; Hessels et al., 2020). The combination of WOW computer stations and bedside scanners enables more timely and efficient delivery of services and documentation completion at the point of care (Tabatabaee et al., 2022).

Medication Errors

Healthcare standards must consider safety, quality, efficiency, and effectiveness as quality indicators. Hence, addressing medication errors is guided by the same indicators to ensure pediatric patients can access safe and quality care. Tabatabaee et al. (2022) assert that medication errors significantly impact patients, healthcare professionals, and the system. Reducing medication errors can result in improved patient safety. When healthcare providers take proactive steps to prevent medication errors, they minimize the risk of violating one of the six rights of medication administration, consequently improving patient care (Tabatabaee et al., 2022).

Al-Worafi (2020) notes that implementing standardized protocols, including double-checking medication orders, and using appropriate labeling systems, can help healthcare providers ensure that medications are administered consistently and accurately. The results are better patient safety and compliance with regulatory requirements and evidence-based practices. Globally, the cost of medication errors exceeded $40 billion in 2022 and are associated with adverse reactions and treatment complications (Al-Worafi, 2020; Rodziewicz & Hipskind, 2020). Implementing strategies to reduce error rates, such as EHRs incorporating medication reconciliation features, barcode medication administration systems, and pharmacist involvement in medication dispensing, can help healthcare facilities reduce medication errors and associated costs (Fisher et al., 2023).

Prevention of medication errors requires a multidimensional approach to mitigation. According to Marufu et al. (2022), the issue is complicated and involves the consideration of a bundle of interventions to achieve successful outcomes. Ghezaywi et al. (2024) point out that collaborative approaches, effective communication, and other human-based interventions are also essential. Based on the literature review, medication errors pose significant concerns since they affect the outcomes of both the patient and the healthcare system. Researchers and healthcare providers have examined several approaches to reducing medication errors and determined that a multidimensional strategy is necessary to achieve accurate medication administration and reduce errors.

Internal Data

A pediatric hospital was experiencing extensive medication-related events in the Southwest United States. The facility implemented several quality management programs and tools, including tracking medication errors, facilitating timely recognition of errors, and implementing interventions. Using tools such as a safety portal, the facility identified medication safety issues using a risk, inventory, and strength evaluation (RISE) and medication dispensing system reports to detect medications delivered without a corresponding order or an override. There are risks associated with overrides, as they bypass established protocols and may result in medication errors, adverse drug reactions, or other safety issues. Identifying overrides through medication dispensing system reports allows healthcare facilities to investigate the root cause of incidents, implement corrective actions, and enhance medication safety processes to prevent future occurrences. Nurses in this pediatric care facility currently use a secure mobile phone device to administer medication at the bedside. Identified medication errors are primarily caused by inadequate visibility of the orders or medication administration record (MAR) within the EMR when viewed on mobile devices. Moreover, using mobile devices presented challenges in handling high-risk medications, scheduling, and implementing the six rights of medication administration.

In pediatric facilities, all stakeholders participate in delivering high-quality, family-centered care, including patients, families, healthcare providers, administrators, support staff, insurance providers, and community organizations. Internal data reports indicated that most medication errors are caused by a lack of expertise among newly graduated nurses. Nurses in this population have limited experience dispensing and administering high-risk medications. Smartphones cannot display the MAR in its entirety, making it difficult to verify the six rights of medication administration. Additionally, it is believed that nurses are overly reliant on technology and have lost sight of assessing and understanding individual patient needs. Based on empirical data, RISE identified 69 medication errors requiring attention (K. Penson, personal communication, January 16, 2021). These reports provided valuable information that can be used to identify gaps, develop interventions, and improve care delivery by decreasing medication errors.

PICOT Question

In a pediatric hospital (P), how do WOW computer stations with barcode scanners (I) compared to currently utilized handheld electronic devices (C) affect medication errors (O) in six months (T)?

Evidence Synthesis

Multiple databases were used to review the literature regarding pediatric medication errors. Databases such as CINHAL, PubMed, Medline, and numerous others were examined. Keywords included *pediatric, paediatric, children, child, medication errors, barcode medication administration, scanners, computer stations,* and *barcode scanners.* A comparison of key terms did not include mobile devices because this resulted in no hits. Pediatrics OR children AND medication errors yielded 191 results in CINAHL, 98 in PubMed, and 101 in Medline. In setting limitations on pediatrics, medication errors, patient safety, drug administration, dosage calculations, randomized controlled trials, English language, and publication date from 2018 to

2024, the final yield decreased to 50 on CINAHL, 30 on PubMed, and 39 on Medline. PsycInfo was also searched, yielding 123 articles after the initial search but 63 after applying the above limits. Additional searches were conducted on the same databases related to pediatric medication errors, but the results were limited.

Among these databases, ten studies were chosen: three randomized controlled trials, two mixed methods studies, one quasi-experimental study, two retrospective analyses, one case-controlled study, and one systematic review that provided sufficient data to determine the importance and role of technology in reducing medication errors. These studies were cross-examined to ensure a comprehensive understanding of how technology can reduce pediatric medication errors. Submitted studies must have been conducted within a pediatric population or simulation, include technology interventions, and illustrate pediatric medication errors. The age range was limited to zero to eighteen, reflecting the pediatric population. Included studies were only published in English, and there were no articles with a publication date before 2018 to ensure contemporary relevance and methodological robustness. Studies not written in English and literature older than five years were excluded to maintain a current perspective. Grey literature and unpublished studies were searched but excluded to prioritize peer-reviewed research, ensuring that conclusions were based on evidence. Titles and abstracts were screened according to inclusion criteria, followed by full-text reviews to assess their suitability for the PICOT. The rigorous process funneled an initially vast data pool into a refined collection, prioritizing methodological quality and relevance.

Ten high-quality studies were retained for this review (see Appendix A, Table A1). Retained studies included three randomized controlled trials, two mixed methods studies, one quasi-experimental study, two simulation studies, and one systematic review (see Appendix A,

Table A1). Fineout-Overholt and Melnyk's (2023) rapid critical appraisal was used to evaluate the quality and strength of the evidence. The evaluation examined the study designs, assessment tools, variables, findings, biases, and implications. Additionally, these articles were quantitative research studies designed to investigate how technology can reduce pediatric medication errors (see Appendix A, Table A1). There was no evidence of bias in the six studies that disclosed their funding source.

Moreover, the studies had adequate sample sizes and moderate demographic information, with participants ages between 0 and 18 (see Appendix A, Table A1, and Table A2). The only exception is the systematic review based on previously published research. Furthermore, data was collected in various settings, including pediatric hospitals and simulation centers (see Appendix A, Table A1, and Table A2).

The studies were conducted in various locations, including two from Iran and eight from Ireland, Switzerland, Australia, Canada, Thailand, Germany, Israel, and the USA. This indicated an inclusive data collection with a broad array of cultural considerations. Significant variables included medication errors and interventions designed to reduce them in pediatric populations. Various measurement tools were utilized, including computer programs and software, smart devices, and platforms that generated information (see Appendix A, Table A2). All studies provided educational interventions concerning the six rights of medication administration, including the right patient, medication, dose, time, route, and documentation. Additionally, computer technologies such as barcode scanning, CPOE, and EMRs were frequently used as interventions (see Appendix A, Table A2). Overall, the studies provided valuable insights into reducing medication errors in pediatric settings, using a variety of theoretical frameworks, study designs, and analytical approaches. Therefore, the studies proved that effective interventions are being implemented to reduce medication errors in pediatric settings. Computer-guided calculations, barcode technology, and electronic medication management systems were common interventions in pediatric healthcare facilities. However, the heterogeneity between studies regarding settings, methodologies, and populations indicated a need for further research to establish standardized prevention measures for reducing pediatric medication errors.

The evidence focused on medication errors in pediatrics, and the results demonstrated that implementing WOWs and standardized protocols leads to eliminating pediatric medication errors and is vital to patient safety and quality care delivery. Medication errors are caused primarily by human error, system disorganization, and issues relating to staff responsibilities. These factors must be considered to formulate effective interventions to reduce medication errors and improve care delivery and patient safety. Additionally, computerized systems such as CPOE and WOW computers with scanners provided promising solutions to decrease medication errors. CPOE automates drug ordering and dispensing processes, whereas WOW computers provide real-time documentation and medication administration at the bedside. As a result of these technologies, medication management is more accurate and efficient, reducing the burden on healthcare systems.

Furthermore, evidence demonstrated the importance of standardized protocols, appropriate labeling systems, double-checking medication orders, and pharmacist involvement in medication dispensing to ensure medication is administered correctly and accurately. Implementing these strategies demonstrates compliance with healthcare regulations, improves patient safety, and adheres to evidence-based practices. Nevertheless, it is essential to note that technology alone cannot prevent medication errors. Heavy workloads, time constraints, and staff exhaustion may hinder the effective use of technology and increase the risk of medication errors.

Therefore, a multifaceted approach that addresses technological and human factors is needed to effectively decrease medication errors in pediatric care settings. Further, the internal data presented from the pediatric hospital illustrates the difficulties newly graduated nurses encounter regarding medication errors. Using mobile devices and relying on technology may result in medication errors resulting from needing more information in EMRs. Healthcare providers must receive continuous training and support to improve safe medication practices.

Purpose

Medication errors are pediatric healthcare systems' most frequently reported medical errors (Gates et al., 2019; San et al., 2019). This paper aims to examine and enhance the understanding of medication errors in pediatrics, emphasize the impact medication errors have on patient safety, identify the factors that contribute to medication errors, and determine how technology can reduce medication errors. Utilizing current research will help to establish the relationship these factors have in contributing to medication errors, and the healthcare system can make evidence-based interventions in response to rising medication error rates, improve care safety, and sustain quality care delivery across the continuum. A comprehensive understanding of risk factors, including system inefficiency, human error, and challenges that arise from staff responsibilities, will help prevent medication errors. All these factors impede the efficient, safe delivery of care.

Theoretical and Implementation Frameworks

A systems thinking approach can be applied to understand and prevent pediatric medication errors. From this perspective, organizations are multidimensional systems of interconnected and interdependent components (McNab et al., 2020). Using systems thinking, medication errors cannot be attributed solely to individual decisions but also to systemic aspects within healthcare organizations. Thus, medication errors do not constitute isolated events but reflect systemic problems such as inadequate training, inadequacies in medication management practices, and workload-related stress among healthcare professionals. In pediatric settings, medication errors are multifaceted and involve the processes of prescribing, dispensing, administration, preparation, and documentation. The stages of a medication management system are interconnected, and errors may occur at any stage due to systemic shortages. Moreover, systems thinking emphasizes integrating technological solutions into the broader healthcare system while considering interactions with existing processes and frameworks (McNab et al., 2020). Addressing systemic issues before implementing new technology, such as computer stations and barcode scanners, minimizes medication errors and enhances quality and safety.

Systems thinking emphasizes collaboration and communication among key stakeholders involved in pediatric medication administration, including healthcare professionals, patients, families, and administrators. An open communication and cooperation culture within healthcare organizations can help identify systemic issues, implement interventions, and measure effectiveness. The systems thinking concept also emphasizes how organizational culture and practices contribute to medication errors (McNab et al., 2020). Pediatric medication errors can be effectively addressed through systemic changes in organizational policy programs, such as providing adequate training for new graduates and reducing overreliance on technology.

The Iowa model was selected as an evidence-based practice model (EBP) to address medication errors in pediatrics. This model integrates clinical proficiency and patient ideals with scientific evidence to guide decision-making and improve patient care. The Iowa model is founded on evidence-based practice and research application (Dusin et al., 2023). Further, the model supports evidence-based practice changes from qualitative, quantitative, clinical proficiency, and background evidence. Using this model, nurses and other healthcare providers were guided through a structured process for implementing evidence-based care.

The Iowa model involves multiple stages: problem identification, evidence review, translation into practice, implementation, and evaluation (Dusin et al., 2023). For example, the occurrence and impact of medication errors in pediatric settings was examined, along with detailed challenges and root causes that led to medication errors. A literature review was conducted utilizing PubMed, CINHAL, and Medline databases to collect empirical evidence on current interventions for reducing pediatric medication errors. A proposed project for implementing WOW computer stations with barcode scanners in pediatric care settings was developed based on the evidence gathered. Implementation occurred in collaboration with key stakeholders, including healthcare providers, information technology (IT) professionals, administrators, patients, and families. A detailed plan was developed describing the steps for installing and integrating WOW computers into existing workflows, training healthcare professionals, and ensuring continuous support and maintenance. An evaluation also determined how WOW computer stations with barcode scanners and training affected medication errors by collecting data on incidents before and after implementation. Quantitative measures on the error rate and qualitative feedback from healthcare professionals, patients, and families are examples of such measures.

Methods

Three ethical principles guided this project: respect for persons, beneficence, and justice. Respect for persons involves treating individuals as autonomous agents with inherent worth and moral value (Bagnasco et al., 2018). The project adhered to this principle by obtaining informed consent from nursing staff (Bagnasco et al., 2018). Nurses participated in educational and informational sessions to assist them in understanding the project's purpose, approach, concerns, and potential benefits. The project also adhered to beneficence. Beneficence is doing good or promoting others' welfare (Cheraghi et al., 2023). The project complied with this principle by establishing safety regulations to protect the general pediatric population from harmful outcomes (Cheraghi et al., 2023). WOWs and scanners were implemented to reduce medication errors during the six rights of administration. Justice is the final principle and is defined as the fair and equitable treatment of all individuals without bias (McDermott-Levy et al., 2018). The project adhered to this principle because WOWs will be a standard of care on all units so that they will be used without bias, provide pediatric patients with the highest quality of care, and rectify any harm caused by errors (McDermott-Levy et al., 2018). Patients received the same standard of care following the six rights of medication administration, and deviations from this standard were minimized. The institutional review boards at the project site and Arizona State University reviewed the project methodology to ensure that ethical principles were followed and participants' human rights were protected. This project did not require patient consent because it pertained to safety protocols, ensuring no harm to the patient. Nursing staff consent was obtained voluntarily and without coercion. Human rights were protected by removing participants' identities and restricting information dissemination.

As part of this project, medication errors were identified and analyzed in a pediatric hospital in the Southwest. An appropriate group of participants was required for the project to achieve its objectives. Participants had to be 18 because they were legal adults and can consent. Participants had to come from various pediatric units within the institution to ensure a diverse sample. Nurse practitioners or nurses employed in pediatric healthcare settings were eligible to participate. To ensure that participants have the necessary training to administer medications independently, they must have completed orientation. Participants had to sign consent forms indicating they were willing to join the study and understood the purpose and procedures involved.

Participants under 18 were not eligible to participate in the study. Conflicts of interest, such as direct involvement in the medication error review process or legal proceedings relating to medication errors, were also excluded. Various methods were utilized to inform potential participants about the project. Nurses working in various pediatric units were invited to participate in the study via email. Additionally, networking events, conferences, and professional associations were utilized to promote the project.

A pre-survey incorporating 22 questions from the Medication Administration Evaluation and Feedback Tool (MAEFT) was distributed to participants in December. The survey answered yes or no questions regarding whether the nurse completed the task.

Additionally, one qualitative question was on the survey to allow nurses to provide feedback regarding the six rights of medication administration and mobile device use. Data collection activities were conducted to assess the status of medication errors and workflow inefficiencies using mobile phone devices to verify the six rights of medication administration. Several months were required for survey collection.

Following the scan of the medication barcode, the nurse ensured that the order matched the EHR, verified the six rights of medication administration, including the correct patient, medication, dose, time, route, and documentation, and administered the medication, updated the EHR in real-time to ensure accuracy and safety.

Furthermore, nurses were consulted for feedback and adjustment. The survey information helped determine whether changes need to be made to mobile phone use in the future based on its effectiveness. The implementation process was modified according to this feedback and evaluation. Barriers were nurses' resistance to change, technological challenges, such as data integration and interoperability, and lack of qualified personnel and supportive resources because of budget and time.

Data was collected using a pre-intervention survey incorporating the MAEFT. A pre-intervention survey focusing on mobile devices was distributed in December before WOW installation with barcode scanners. A post-intervention survey will be administered in the future after implementing WOWs to assess the usage of mobile devices and WOW computer stations equipped with barcode scanners. To facilitate the completion of the surveys by as many nurses as possible, the surveys were distributed in person and with a quick response code (QR). Surveys incorporated the MAEFT by using checkbox questions to evaluate each of the six rights related to medication administration. In the surveys, nurses were asked to provide feedback regarding how the technology-assisted or hindered their ability to follow the six rights of medication administration. Data collected assessed how mobile phones impacted the six rights, safety, and staff satisfaction.

Demographic information was obtained through the pre-intervention surveys, including age, gender, ethnicity, education, and years of nursing experience. An encrypted database stored all collected data within the hospital's IT infrastructure. Only authorized personnel had access to this database. All data was retained for five years, after which it will be securely archived or anonymized. The data was accessible via role-based permissions to ensure that only healthcare providers and project staff had access to the data. All data used for reporting purposes were anonymized or masked to protect participant privacy. Health Insurance Portability and Accountability Act (HIPAA) regulations and hospital policies regarding participant and patient privacy and security were followed when handling data. These measures ensured that participant demographics were collected responsibly and stored securely, ensuring confidentiality and privacy.

The outcome measures included a gap analysis on mobile phone use, nurse adherence to the six rights of medication administration, and nurse satisfaction. Based on the evidence, staff adherence to the six rights of medication administration was observed, staff satisfaction did increase, workflow efficiency was enhanced, and time was saved during medication administration tasks. This provided insight into how education and training can reduce pediatric medication errors and improve patient outcomes. Nevertheless, further research is needed to address the reluctance to adopt this advancing technology.

MAEFT assessed several efficacy indices for medication administration, including accuracy, safety, staff and patient interaction protocol compliance, and patient satisfaction. Overall, these outcome variables provided insight into the quality and effectiveness of medication administration procedures in healthcare settings (Davies et al., 2023). Additionally, the tool assessed dose accuracy, administration method, and frequency. In addition to ensuring safety, MAEFT safeguarded patient well-being by systematically assessing factors or conditions that may lead to adverse medication occurrences (Davies et al., 2021). Moreover, the tool assessed health professionals' adherence to established practices when administering medications. Utilizing protocols standardizes various aspects of patient care, enhancing reliability.

Additionally, the instrument facilitated communication among members of the healthcare team. This measure benefited patients by organizing medication administration processes, avoiding confusion, and protecting patients. This aspect of communication contributed to teamwork development and ensured that each member was aware of the information, goals, and operations in progress (Davies et al., 2021).

MAEFT was an effective tool for addressing pediatric medication errors. Using the MAEFT, healthcare organizations can outline how medication management may be assessed and improved. This tool was beneficial when evaluating the effectiveness of medication administration and the challenges involved in achieving improved patient outcomes (Davies et al., 2021). MAEFT facilitated the evaluation of factors necessitating medication administration, including dosage, method of administration, and other requirements outlined in the guidelines. Incorporating this instrument into an organization fosters accountability and perseverance, improving patient safety and experience.

MAEFT was compared to standard medication administration quality and safety measures, such as error rates and adverse events. A relatively high correlation between experimental MAEFT scores and these objective measures supported the instrument's criterion validity (Davies et al., 2021). Using MAEFT, a group of raters evaluated different medication administration scenarios. Cohen's Kappa coefficient was used to check inter-rater reliability while rating the responses. Fleiss's Kappa coefficient was 0.77, indicating excellent agreement and inter-rater reliability (Davies et al., 2021). Nurses and observers found the tool helpful and practical for evaluating medication administration practices in clinical settings.

To analyze the data, descriptive statistics summarized qualitative responses from nursing surveys, providing insights into common themes and perceptions. Using thematic analysis, the qualitative responses to the open-ended survey questions were analyzed to determine how nurses perceive the technology's impact on the safety and accuracy of medication administration and workflow efficiency. Quantitative variables were expressed as mean, median, and range, while categorical variables were expressed as frequencies and percentages. Pre-intervention analyses of medication administration effectiveness and efficiency was conducted using descriptive statistics with cross-tabulation.

Outcomes

Intellectus Statistics Software was used to store, manage, and analyze the data (Intellectus Statistics, 2023). The sample included nurses in a Pediatric Intensive Care Unit (PICU) (n=16). Participants were over 18 years of age and completed orientation in the PICU. Statistical descriptive methods, including frequencies and percentages, were used to summarize medication administration practices among the participating nurses. Several interval and ratio variables were analyzed using means, standard deviations, and ranges. Cross-tabulation was used to explore relationships between years of experience and performance on key medication safety tasks, such as identifying patients and checking medications at the bedside.

Frequencies and percentages were calculated to describe the outcome variables (see Appendix B, Table B1). The first criteria for medication administration were checking the name and birthday. Half of the sample correctly identified the patient, and the other half did not do so in this manner. Most of the sample identified the right patient 15 (94%), and the remainder did not 1 (6%). Checking patient allergies and adverse drug reactions resulted in 6 (34%) nurses completing the task while 9 (56%) did not. 1 (6%) participant's answer was skewed with a yes and no answer. The majority, 13 (81%), updated allergies and/or discussed discrepancies with the provider, while 3 (19%) did not complete the task. All 16 (100%) participants completed the medication administration tasks of checking the medication against the order and ensuring it was indicated for the patient's diagnosis and that there were no duplicate orders.

The majority, 13 (81%), checked the medication expiration date, while 3 (19%) did not complete the task. All 16 (100%) nurses completed the right time, frequency, and route tasks. The majority, 14 (88%), checked the medication dose against the order and confirmed the dose, while 1 (6%) did not, and 1 (6%) answered both yes and no. All 16 (100%) participants completed the following medication administration tasks of right to refuse, patient observations before administration, hand hygiene and using appropriate personal protective equipment, maintaining aseptic technique when preparing and administering, completing the correct administration technique of intravenous (IV) injectable line setup, and added correct additive medicine and completed line labels.

The majority, 15 (94%), confirmed that the medication needed a two-nurse check for calculations, while 1 (6%) did not complete the task. The majority, 14 (88%), completed two nurses witnessing the medication preparation, while 2 (12%) did not complete the task. 12 (75%) participants completed the two-nurse bedside medication check if required, while 3 (19%) did not, and 1 (6%) answered both yes and no. 10 (63%) nurses asked the patient or family if they knew what the medication was for, while 6 (37%) did not complete the task. All 16 (100%) nurses witnessed the patient taking or self-administering the medication and completed the medication documentation.

Descriptive Statistics

Summary statistics were calculated for each interval and ratio variable, and frequencies and percentages were calculated for each outcome variable (Intellectus Statistics, 2023).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to the name and date of birth (DOB). The average number of years of experience as a registered nurse was 5.69 (SD = 4.12), and the number of years ranged from ½ to 13 years, asked for name and DOB (see Appendix C, Table C1).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to the right patient. The average number of years of experience as a registered nurse was 8.07 (SD=9.34), and the number of years range from ½ to 38 years, identified the right patient (see Appendix C, Table C2).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to patient allergies and adverse drug reactions. The average number of years of experience as a registered nurse was 9.50 (SD = 14.18), and the number of years ranged from ½ to 38 years, checked patient allergies and adverse drug reactions (see Appendix C, Table C3).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to update allergies and/or discuss discrepancies with the provider. The average number of years of experience as a registered nurse was 8.19 (SD = 9.82), and the number of years ranged from ½ to 38 years, with updated allergies and/or discussed discrepancies with the provider (see Appendix C, Table C4).

Descriptive cross-tabulation statistics was used to compare the years worked to check the medication against the medication order. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, checked the medication against the medication order (see Appendix C, Table C5).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to check medication is indicated for the patient's diagnosis and that there are no duplicate orders. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years; checked that the medication was indicated for the patient diagnosis and that there were no duplicate orders (see Appendix C, Table C6).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to check the medication expiration date. The average number of years of experience as a registered nurse was 7.65 (SD = 9.69), and the number of years ranged from ½ to 38 years, checked the medication expiration date (see Appendix C, Table C7).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to check the medication dose against the medication order and confirmed dose. The average number of years of experience as a registered nurse was 8.32 (SD = 9.64), and the number of years ranged from ½ to 38 years, checked the medication dose against the medication order and confirmed the correct dose (see Appendix C, Table C8).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to confirm the right route. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, confirmed the right route (see Appendix C, Table C9).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to confirm the right time and frequency. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, confirmed the right time and frequency (see Appendix C, Table C10).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to complete the right to refuse. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, completing the right to refuse (see Appendix C, Table C11).

Cross-tabulation descriptive statistics was used to compare the years worked to conduct patient observations before medication administration. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, conducted patient observations before medication administration (see Appendix C, Table C12).

Cross-tabulation descriptive statistics was used to compare the years worked to complete hand hygiene and use appropriate personal protective equipment. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, completed hand hygiene and used appropriate personal protective equipment (see Appendix C, Table C13).

Cross-tabulation descriptive statistics was used to compare the years worked to perform the aseptic technique when preparing and administering medication. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, performed aseptic technique when medication was prepared and administered (see Appendix C, Table C14).

Descriptive statistics using cross-tabulation was used to compare the years worked to complete the correct administration technique of intravenous (IV) injectable line setup. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, completing the correct administration technique of IV injectable line setup (see Appendix C, Table C15).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to the completion and addition of correct additive medicine and labeling lines. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, completed and added correct additive medicine and labeled lines (see Appendix C, Table C16).

Descriptive statistics using cross-tabulation was used to compare the number of years worked and confirm that the medication requires two nurses to check medication calculations. The average number of years of experience as a registered nurse was 8.10 (SD = 9.33), and the number of years ranged from ½ to 38 years, confirmed that the medication required two nurses to check medication calculations (see Appendix C, Table C17).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to complete both nurses witnessing medication preparation. The average number of years of experience as a registered nurse was 7.43 (SD = 9.35), and the number of years ranged from ½ to 38 years, completed both nurses witnessed medication preparation (see Appendix C, Table C18).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to the number of nurses who go to the bedside if a double check of the medication is required. The average number of years of experience as a registered nurse was 9.00 (SD = 10.31), and the number of years ranged from ½ to 38 years, with both nurses going to the bedside if a double check of the medication was required (see Appendix C, Table C19).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to asking the patient or family if they know why they are taking the medication. The average number of years of experience as a registered nurse was 10.15 (SD = 10.98), and the number of years ranged from ½ to 38 years; asked the patient or family if they knew why they were taking the medication (see Appendix C, Table C20).

Descriptive statistics using cross-tabulation was used to compare the number of years worked to witnessing the patient taking or correctly self-administering the medication. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, witnessing the patient take or correctly self-administered the medication (see Appendix C, Table C21).

Descriptive cross-tabulation statistics was used to compare the years worked to document medication administration. The average number of years of experience as a registered nurse was 7.88 (SD = 9.05), and the number of years ranged from ½ to 38 years, documented medication administration (see Appendix C, Table C22).

Two nurses provided feedback comments on mobile phone use and the six rights of medication administration. One nurse stated, “Sometimes if the provider changes the frequency of a medication (for example, Q6 hours to Q12), the medication will no longer scan, even though it is an appropriate dose. Nurses usually have a nurse double check that the dose is appropriate and administer anyway so that the medication is not late.” A second nurse commented “When phone isn't working, you have to power down and restart which consumes time. If the restart doesn't work, we have to go find a new phone and restart the process. Phones are very sensitive and a lot of times we have to keep re-scanning things, which also consumes a lot of time.”

Results

Among the sixteen nurses observed, 50% correctly identified patients using their name and date of birth, indicating partial compliance with standard verification protocols. Furthermore, 25% of nurses did not double-check the medication at the bedside, with one nurse giving a non-committal "Yes and No" response. Since the sample size was small and the study was descriptive, a statistical significance calculation was not performed; however, the findings may have clinical significance by pointing out potential gaps in medication safety practices that may increase the risk of medication errors.

Complying with the six rights of medication administration protocols was variable, highlighting the need for continued education and reinforcement of best practices. As a result, patients' safety and trust in their care are directly affected. Providers can use the findings to develop targeted training and accountability initiatives. The results support the need for standardized policy enforcement and the potential integration of automated safety checks and reminders into electronic health records.

Continuous education, competency assessments, and real-time feedback should be incorporated into clinical practice to sustain improvements. Compliance can be reinforced by incorporating routine audits and clinical champions as models. Moreover, aligning medication safety protocols with organizational policies and performance evaluations can contribute to long-term adherence and cultural changes.

Discussion

PICU nurses' compliance with the six rights of medication administration was evaluated through a gap analysis. The results of empirical data showed that every nurse (100% of 16 participants) adhered precisely to the safety protocol regarding hand hygiene, appropriate use of personal protective equipment, compliance with documentation procedures, aseptic methods, and accurate IV setup. All staff members checked that the medication was administered according to the correct schedule, delivery route, and dosage frequency. Approximately half of nurses confirmed the identification of patients by their full names and date of birth; however, 93.75% of nurses conducted some form of identification. In the survey, 81.25% of nurses checked and updated allergies, whereas 62.5% discussed medication purposes with patients and families. The results suggest that despite the high level of compliance, adherence to the six rights of medication administration is inconsistent.

Several limitations impacted the study. The findings may not apply to broad populations because of the limited sample size of sixteen. The project was shifted to a gap analysis because of secondary funding. The inconsistencies in identifying the right patient and other responses within the study may relate to unclear protocol interpretation or workflow challenges. Single-site design creates barriers to research application.

According to Luokkamäki et al. (2021), nurses administer medication effectively; however, safety protocols such as identity verification remain inconsistent. Manias et al. (2020) noted that medication safety lapses persist despite training initiatives due to communication breakdowns and systematic problems in the workflow process. Alhur et al. (2024) demonstrated that direct patient interaction and interprofessional communication reduce medication errors. As a result of the survey, 62.5% of nurses did not verify that patients or their families understood their medications, highlighting the need for improved communication methods to be incorporated into nurses' daily routines.

Simulations that combine team-based drills with educational material are effective methods of maintaining and strengthening best practices. A study conducted across various healthcare settings and staff clusters with different experience levels would strengthen the findings. Qualitative research must examine why healthcare providers do not adhere to specific protocols.

Data indicated that practices adhered to essential medication safety protocols, but significant non-adherence was observed regarding patient identification procedures and medication education practices. These documented inadequacies confirm research findings, demonstrating the necessity of ongoing structured education interventions. In pediatric and critical care medicine, interprofessional communication improves medication safety outcomes.

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Appendix A

Evaluation and Synthesis Tables

Table A1

Evaluation Table for Quantitative Studies

Citation	**Theoretical/ Conceptual Framework**	**Design/ Method/ Purpose**	**Sample/Setting**	**Variables**	**Measurement/ Instrumentation**	**Data Analysis**	**Results/ Findings**	**Level of Evidence; Application to practice; Generalization**
Aletayeb et al., (2019), Identifying medication errors in neonatal intensive care units: A two-center study. **Country**: Iran **Funding**: Grant Ahvaz Jundishapour University of Medical Sciences **Bias**: No bias was noted, and no competing interests were declared—possible bias	• Donabedian model • Health Belief Model • Physiologic Model	**Design:** Descriptive cross-sectional study **Purpose:** To determine the type and frequency of ME, identify risk factors, and take practical steps to reduce ME. Investigate the quality of prescriptions.	**N=** 155 neonates; Male=102; F=53 Preterm=76 Low-birth weight=71 Out born=100 Discharged alive=141 **Demographics:** Neonates divided by categories of birth weights, gestational age or preterm, and length of stay **Setting:** 2 NICUs at Abuzar (15 beds) and Imam Khomeini (45 beds, Level 3)	**IV1:** ME **DV1:** Wrong dose **DV2:** Wrong route of administration **DV3:** Wrong dosing interval **Definitions:** • ME • Kardex • Prescription Errors • Administratio n Errors	**Tools:** • Recorded ME from extracted meds from order sheets. • Transcribed to Kardex. **Validity/ Reliability:** Not applicable to the tools above.	**Statistical Tests Used:** • Mean and standard deviation • Median and interquartil e range • T-Test • Mann-Whitney • Fisher's • Chi-Square • Wilcoxon • Logistic Regression	**DV1:** 142 wrong dose errors (28%) (Prescribing phase higher in preterm than term $P < 0.005$) **DV2:** 104 wrong route errors (20.4%) (Length of stay associated with wrong route $P < 0.014$) **DV3:** 43 wrong dosing intervals (8.4%) (Length of stay associated with wrong dosing	**Level of Evidence**: IV **Strengths**: • Compared findings to other studies and had similar findings • Different types of prescription and administration errors enhanced the specificity **Weakness**: • Inability to gauge critical errors • Scant knowledge regarding the

Key: **ADE** Adverse Drug Events, **ADR** Adverse Drug Reaction, **CI** Confidence Interval, **CPOE** Computerized Provider Order Entry, **DV** Dependent Variable, **ED** Emergency Department, **eMAR** Electronic Medical Administration Record, **EMS** Electronic Medication System, **F** Female, **IV** Independent Variable, **JITI** Just-In-Time Information, **MAE** Medication Administration Error, **MAP** Medication Administration Process, **ME** Medication Error, **NICU** Neonatal Intensive Care Unit, **RCT** Randomized Controlled Trial, **RN** Registered Nurse, **RRR** Relative Risk Reduction, **SIM** Simulation, **SWCRCT** Stepped-Wedge Cluster Randomized Controlled Trial

without randomization.			hospitals in Ahvaz, Southwest Iran **Exclusion:** • Parenteral nutrition • Topical Meds • Serums and electrolytes • Oxygen therapy • Blood products • Vaccines • Vitamins • Contrasts **Attrition:** 0%				intervals P < 0.007)	effects of errors • Using many variables for ME • ME was recorded, but development was not interpreted **Feasibility**: Study reveals frequent errors relating to wrong dosage by prescription, non-administration of med, and lack of time. **Application**: Findings can help raise awareness regarding ME in NICUs.
Berg et al., (2021), use simulation to measure the effects of just-in-time information to prevent nursing medication errors.	• Benner's nursing skill acquisition theory. • Kolb's experiential learning theory.	**Design:** RCT **Purpose:** • To measure whether JITI affects the occurrence of medication administration errors.	**N=** 93 across two semesters. 38 groups were included, with 2 to 3 senior nursing students in every group. **CG:** n= 50 in fall semester **IG:** n= 43 in spring semester	**IV1:** Nursing ME **DV1:** JITI **DV2:** App use with limited training **DV3:** App use with extended training	**Tools:** • Pediatric MAP Simulation. • Smart device app. **Validity/ Reliability:** • Accurate dose	**Statistical Tests Used:** • Chi-Squared test • Fisher's exact test • Phi coefficient	**DV1:** Completed SIM better (*P* < 0.002; coefficient 0.573) **DV2:** Decreased chance of SIM completion	**Level of Evidence**: II **Strengths**: • SIM instead of the clinical setting. • No harm to patients. • Same mannequin.

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Country: USA **Funding**: None **Bias**: Possible bias if training on the use of apps to reduce the effect of lack of app familiarity on outcomes.			**Demographics:** • 24 groups included senior students in pediatric course semester 1. • 11 included nurses in the pediatric course semester 2. **Setting:** University of Tennessee-Knoxville simulation. **Exclusion:** None **Attrition:** 0%	**Definitions:** • MAE • JITI • ME • MAP	calculation; limited need for nurse-patient interaction; allowed surrogate information source. • Deliver JITI, providing on-demand key medication administration information.		**DV3:** Increased rate of SIM completion (*P* < 0.013; coefficient 0.611)	• Same voice. • Same standardized person. • The entire cohort participated. **Weakness**: • Limited to undergraduate students in final year. • The cohort may not have been a uniform population. • The measure of app elements is not completed. • SIM is required in conjunction with a course. **Feasibility**: Effective use of the app is essential in SIM; lowering the risk of MAE. Provides an intervention to promote nurse's competency in reducing MAE.

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								Application: Supporting SIM method in lowering MAE in the pediatric setting.
Chongthavonsatit et al., (2021), Comparison of accuracy and speed in computer-assisted versus conventional methods for pediatric drug dose calculation: A scenario-based randomized controlled trial. **Country**: Thailand **Funding**: None **Bias**: None stated: No potential conflict of interest declared. Possible bias using only	• Human Error Model • Organizational Learning Model	**Design:** Randomized crossover experimental **Purpose:** • To assess the effects of computer-assisted calculation on reducing error rates and time to prescription of specific emergency drugs	**N=** 562 prescriptions (336 from 20 emergency medicine residents; 224 from 14 paramedics) Two prescriptions excluded **CG:** n= 280 **IG:** n= 280 **Demographics:** • Emergency medicine residents and Paramedics **Setting:** Department of Emergency Medicine in Ramathibodi Hospital: University-	**IV1:** 4 Written paper-based scenarios for writing prescriptions **DV1:** Conventional method **DV2:** Computer-assisted method **Definitions:** • ME • Computer-assisted calculation • Drug dosage calculation • Pediatric dosing error	**Tools:** • Computer-calculated dosing • STATA Version 16.0 analysis software • Recorded in numbers on MacOS program version 5.1 **Validity/ Reliability:** • Found sole variable contributing to reduced errors (Adjusted relative risk=0.436, 95% CI 0.336-0.520, P<.001)	**Statistical Tests Used:** • Logistic regression analysis presented numbers and percentages • Quantile regression analysis presented medians with interquartile ratios	**DV1:** Meds less accurately calculated with the conventional method (57.86% with 162/280 correct; P < 0.001) **DV2:** Meds more accurately calculated with computer-assisted method (89.29% with 250/280 correct; P < 0.001)	**Level of Evidence**: II **Strengths**: • Compared findings to other studies. • Used block randomization scheme. • Participants used both methods. **Weakness**: • Paper-based scenarios instead of actual patients. • Over one year is required to compile sufficient prescriptions for analysis, making randomization impossible.

Key: **ADE** Adverse Drug Events, **ADR** Adverse Drug Reaction, **CI** Confidence Interval, **CPOE** Computerized Provider Order Entry, **DV** Dependent Variable, **ED** Emergency Department, **eMAR** Electronic Medical Administration Record, **EMS** Electronic Medication System, **F** Female, **IV** Independent Variable, **JITI** Just-In-Time Information, **MAE** Medication Administration Error, **MAP** Medication Administration Process, **ME** Medication Error, **NICU** Neonatal Intensive Care Unit, **RCT** Randomized Controlled Trial, **RN** Registered Nurse, **RRR** Relative Risk Reduction, **SIM** Simulation, **SWCRCT** Stepped-Wedge Cluster Randomized Controlled Trial

emergency personnel.			affiliated super tertiary **Exclusion:** None **Attrition:** 0.35%					**Feasibility**: Computer-assisted method improves prescribing speed and drug calculations. **Application**: The computer-assisted method provides advantages in reducing prescription errors and calculation time.
Liang et al., (2023), Improving medication safety in a paediatric hospital: A mixed-methods evaluation of a newly implemented computerized provider order entry system. **Country**: Canada **Funding**: A grant from MEDTEQ's and	• Meta-model framework • Social Learning Theory	**Design:** Mixed methods pre-post observational study **Purpose:** • Measure and contextualize the impacts of CPOE adoption • Describe CPOE implementatio n and med ordering workflows before and after	**N=** 60 pediatric beds **Demographics:** • General pediatric unit: 4 medical teams with one attending, medical residents, students, two clinical pharmacists, four nursing stations	**IV1:** CPOE **DV1:** ME pre-CPOE implementation **DV2:** ME post-CPOE implementation **Definitions:** • MAP • ME • CPOE	**Tools:** • Pharmacy information system • EMS • Clinical data repository • Lab and Radiology ancillary information system **Validity/ Reliability:** • Not applicable to tools above	**Statistical Tests Used:** • Poisson rate ratio • Chi-Squared Test • CI	**DV1:** 133 ME out of 28,302 orders (Rate ratio 1.2; 95% CI 0.8 to 1.7) **DV2:** 109 ME out of 27,887 orders (Rate ratio 1.2; 95% CI 0.8 to 1.7)	**Level of Evidence**: III **Strengths**: • On-unit pharmacists reviewed med regimens during ordering, preventing errors from the patient. • The general paediatric unit represents the largest in the hospital. • 1st pediatric hospital to implement

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conducted as part of graduate degree research project, supported by a scholarship from the Canadian Institutes of Health Research (CIHR) **Bias**: None were stated, and no competing interests were declared—possible bias with training and modules.		• Describe the rate and types of clinical errors during various stages of med management process • Identify potential health information technology (HIT) related prevention strategies based on error reports	**Setting:** 60-bed general pediatric unit at CHU Sainte-Justine; an academic mother-child health center with over 400 beds. **Exclusion:** None **Attrition:** 0%						CPOE and 1st unit to pilot • Completed training modules and scenario testing one month before Go-live • Phone line support 24/7 for four months **Weakness**: • Based on data from error reporting. • The prevalence of medical errors is higher than reported. • It was only conducted on one pilot unit. • Fewer error reports in 1st month following CPOE implementation. **Feasibility**: Provides valuable insights about

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								CPOE; recommendations viable to practice. **Application**: CPOE implementation significantly reduces med errors.
Westbrook et al., (2022), Short- and long-term effects of an electronic medication management system on paediatric prescribing errors. **Country**: Australia **Funding**: National Health and Medical Research Council partnership project grant with Sydney Children's Hospital Network.	• Health Belief Model • Physiologic Model	**Design:** SWCRCT **Purpose:** • To assess an electronic medication management system's short- and long-term effectiveness in reducing prescribing errors.	**N=** 4,821 patients **CG:** n= 1,686; F 691 **IG:** n= 2,096; F 838 **IG:** n= 1,039; F 460 **Demographics:** • Pediatric Patients **Setting:** 310-bed pediatric referral hospital in Sydney **Exclusion:** None stated **Attrition:** 0%	**IV1:** Paper charts **DV1:** EMS use in 1st 70 days **DV2:** EMS use post one year **Definitions:** • MAE • JITI • ME • MAP	**Tools:** • None Stated **Validity/ Reliability:** • None Stated	**Statistical Tests Used:** • Poisson • Generalized linear mixed-effects negative binomial • $\chi 2$	**DV1:** No significant decrease in overall clinical prescribing error rates (IRR 1.05; 95% CI (0.92-1.21) **DV2:** 1-year follow-up showed a significant 36% reduction (IRR 0.64; 95% CI 0.56-0.72) in overall clinical prescribing errors compared to the paper period.	**Level of Evidence**: II **Strengths**: • One year follow-up • Randomized • Mandatory training close to implementation. **Weakness**: • Absence of investigations and monitoring information. **Feasibility**: Analyzes EMS as an intervention for MAE in pediatrics. **Application**: Outcomes guide

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Bias: Possible bias if a cluster randomized controlled trial was used; therefore, a step-wedged cluster randomized trial was used.								the implementation and integration of EMS into clinical practice.
Kung et al., (2021), Effect of barcode technology on medication preparation safety: A quasi-experimental study. **Country**: Switzerland **Funding**: Grant: Innosuisse-Swiss Innovation Agency **Bias**: Researchers' reliance on clinical leaders may engender bias.	• Donabedian model • Social learning theory	**Design:** Quasi-experimental study with pre-post design. **Purpose:** • Analyze effects of new barcode-assisted med process on med preparation errors. • Compare the time spent on med preparation tasks by RNs.	**N=** 13 RNs; 8 at baseline; 5 after system implementation. **N=** 5,932 medication doses; 2,726 before; 3,206 after implementing the barcode system. **Demographics:** • 7 F RNs with an average age 30.5 at baseline; 4 F RNs with an average age of 27.9 post-intervention • Observed F patients = 25 (29.4%) at baseline;	**IV1:** Barcode Scanning **DV1:** Med prep errors **DV2:** Staff time performance **Definitions:** • ME • ADE • Barcode technology • Closed-loop med management • Odds Ratio (OR) • Wrong med • Wrong dose • Wrong patient • Wrong time • Wrong form	**Tools:** • Stata version 13.1 **Validity/ Reliability:** • 95% reliability	**Statistical Tests Used:** • Unadjusted and adjusted logistic models for error frequencies • Linear regression models for time performanc e • Odds ratio • Beta • CI • Mean • Standard deviation	**DV1:** Med prep errors reduced from 9.9% to 4.5% post-intervention (P < 0.001; OR 0.42). Ambiguous dispenser, wrong form, and wrong patient errors decreased from 33, 8, 20 to 0 post-intervention. Total RRR 54.5% **DV2:** Time used for med prep process reduced from 30.2 to 17.2 min. (P=0.047, Beta -6.5). The	**Level of Evidence**: III **Strengths**: • Direct observation was used, which is the gold standard of ME detection. • **Weakness**: • The pre-post design had no control group or randomization. • The barcode med system was designed with users and clinical leaders to support change.

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			Post Intervention 47 F (42.3%) **Setting:** 2 mixed med/surg units; 1,037-bed tertiary teaching hospital in Switzerland. **Exclusion:** None stated **Attrition:** 0%	• Omission • Omission due to human factor • Omission due to technical reason • Omission due to logistic • Additional dose			mean time to prepare one single med dose decreased from 24.3 to 15.1 sec. (P=0.002, Beta -5.0)	• Funds are required for training, software teams, and hardware. • RNs improved performance under direct observation. **Feasibility**: Barcode technology can be adapted to hospitals using similar processes. **Application**: Barcode assisted med prep process significantly reduces time for med prep tasks.
Conn et al., (2020), Characteristics of reported pediatric medication errors in Northern Ireland and use in quality improvement.	• Theoretical domains framework • Social learning theory	**Design:** Retrospective observational analysis **Purpose:** • Identify priority targets for quality improvement by analyzing	**N=** 1,522 extracted Mes from 1,467 incident reports **Demographics:** • Pediatric patients age 0-16; including 380,000 children	**IV1:** Reported Mes **DV1:** Type of ME **DV2:** Degree of harm from Mes **DV3:** Age of patient	**Tools:** • Microsoft Excel Spreadsheet **Validity/ Reliability:** • Not applicable to the tool above	**Statistical Tests Used:** • Descriptive statistics	**DV1:** Prescribing (n=517; 34%); Administration (n=822; 54%); Prep/Dispense (n=143; 9.4%); Monitoring (n=37; 2.4%); Other (n=3; 0.002%)	**Level of Evidence**: III **Strengths**: • Data from the entire region • One of the largest studies of reported Mes in children

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Country: Ireland **Funding**: Research fellowship: Royal Belfast Hospital for Sick Children **Bias**: Possible bias with incomplete or inaccurate data		error types, characteristics, and risk areas; triangulating findings against published evidence; informed opinion of the advisory panel of experienced clinicians.	**Setting:** Obtained all reported Mes from 2011-2015 in all 5 Northern Ireland Health and Social Care Trusts. Various settings: children's hospital, 7 district hospitals, NICU. **Exclusion:** Primary care; Mes not relating to patients, ADEs with no Mes, errors in primary care but reported in secondary care, errors related to medical devices or equipment. **Attrition:** 0%	**Definitions:** • Risk • Mes • ADRs			**DV2:** Insignificant (n=1,130; 74.2%); Minor (n=375; 24.6%); Moderate (n=17; 1.1%); Severe (n=0); Catastrophic (n=0) **DV3:** 0-27 days (n=291; 19.1%); 28 days-12 months (n=230; 15.1%); 13 months-2 yrs. (n=75; 4.9%); 2-5 yrs. (n=220; 14.5%); 6-11 yrs. (n=219; 14.4%); 12-16 yrs. (n=324; 21.3%); Not specified (n=163; 10.7%)	• Triangulation of findings with experts • Published evidence **Weakness**: • Reliance on existing incident reports • Mes less likely to be incomplete: vetted by Med Governance Pharmacists after reporting • Not all risks identified using incident data **Feasibility**: Implementation in organizations with established incident reporting systems. **Application**: Provides insight for prioritizing quality improvement efforts in pediatric med safety.

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Karimian et al., (2018), Medication errors associated with adverse drug reactions in Iran (2015-2017): A p-method approach. **Country**: Iran **Funding**: Non-restricted grant from the Deputy for Science and Technology of the President's Office. **Bias**: No evident bias	• Iowa model • Stetler model of research use and evidence-based practice	**Design:** Retrospective analysis **Purpose:** • Characterize Mes associated with ADRs	**N=** 17,988 ADR reports over 2 yrs. n= 1,231 pADRs included in the study Year 1, n= 8,205 ADRs; 601 pADRs. Year 2, n= 9,783 ADRs; 630 pADRs **Demographics:** • n= 206 peds patients • n= 1,025 adult patients **Setting:** National Pharmaco-vigilance (PCV) within Iran's Food and Drug Administration (2015-2017) **Exclusion:** None stated **Attrition:** 0%	**IV1:** Mes **DV1:** Preventable ADRs **DV2:** Med classification **DV3:** Incident reporters **Definitions:** • Mes • ADR • Preventable ADRs • Serious ADR • Med classification • Patient age groups	**Tools:** • P-method • Yellow Cards (paper-based; online forms) • WHO-UMC Causality Assessment System • Microsoft Excel Software • SPSS version 18.0 **Validity/ Reliability:** • It does not apply to yellow cards, excel, and SPSS. Validated; WHO guidelines followed	**Statistical Tests Used:** • Descriptive statistics • CI	**DV1:** Most frequent pADR, having documented hypersensitivity to administered drug/drug class (61.23% yr. 1; 54.29% yr. 2) **DV2:** Anti-infectives for systemic use (n=656; 53.29%) Serious (n=29; 39.19%). Nervous system (n=190; 15.43%) Serious (n=5; 6.76%). **DV3:** Majority pADRs reported by RNs (n=881; 71.57%)	**Level of Evidence**: III **Strengths**: • Internal audit system assuring data before use by decision-makers • National-level data • Standardized assessment method • Followed guidelines from the WHO **Weakness**: • P-method modified in 2nd yr. Data could not be statistically compared for two years to detect the difference. • The preventable ADR rate likely underestimated the true extent

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								of ADR prevalence. **Feasibility**: Pediatric patients are most vulnerable to Mes; and develop more unknown or rare ADRs. **Application**: Applying the P-method helps determine preventable criteria that led to occurrence.
Eisenbach et al., (2020), The effect of an interventional program on the occurrence of medication errors in children. **Country**: Israel **Funding**: None: Work was performed as required for the MD thesis.	• Lewin's theory of planned change • Rosswurm and Larrabee model	**Design:** Observational Case-Control **Purpose:** • Examine the incidence of pediatric med dosing errors • Impact of intervention program in reducing errors and related	**N=** 100 pediatric Otolaryngology elective admissions/ED n= 142 prescriptions pre-intervention n= 363 meds administered pre-intervention n= 113 prescriptions post-intervention n= 303 meds administered post-intervention	**IV1:** Program intervention: Education, meetings, med-dosing notes on each computer, computer link Micromedex, mobile app Micromedex, avoided specific meds with a limited safety profile **DV1:** Prescription errors pre- and post-intervention	**Tools:** • Computer network link for IBM Micromedex Drug Ref • Smartphone app IBM Micromedex Drug Ref • IBM SPSS software version 21.0 **Validity/ Reliability:** • None applicable to	**Statistical Tests Used:** • Kolmogorov Smirnov test • Independent t-test • Mann-Whitney U test • χ2 • Z Test • Chi-Squared test • Fisher's test	**DV1:** Pre-intervention prescription errors (n= 33; 23.2%). Post-intervention prescription errors (n=12; 10.6%). Pre-and-post (Z test 2.626; p = 0.01) **DV2:** Pre-intervention administered med errors (64; 17.6%).	**Level of Evidence**: III **Strengths**: • Three staff members examined each case. • Case disagreement resolved with joint discussion. **Weakness**: • Based on eMARs

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Bias: Possible bias with lack of blinding in intervention implementation		adverse effects	**CG:** n= 50 patients' pre-intervention **IG:** n= 50 patients' post-intervention **Demographics:** • Pediatric patients 12 yrs. or younger • Pre-intervention mean age = 5.6; 64% M • Post-intervention mean age = 4.9; 60% M **Setting:** Tertiary pediatric medical center; Otolaryngology Department; Galilee Medical Center **Exclusion:** None stated **Attrition:** 0%	**DV2:** Administered med errors pre- and post-intervention **Definitions:** • ME • ADE	the above tools	• Mean and standard deviation	Post-intervention administered med errors (21; 7%). Pre-and-post (Z test 4.121; p < 0.001).	• Information collected retrospectively • Gaps between prescribed meds to actual meds given, med prep mistakes, documenting errors. **Feasibility**: Mes are common among hospitalized children; intervention programs effectively improve this vulnerable population's safety. **Application**: A combined approach to reduce Mes provides solutions for several prevalent problems.
Koeck et al., (2021), Interventions to	• Hierarchy of controls model	**Design:** Systematic Review	**N=** 20 selected studies	**IV1:** Mes	**Tools:** • Cochrane tool	**Statistical Tests Used:**	**DV1:** Interventions of substitution	**Level of Evidence**: I

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reduce medication dispensing, administration, and monitoring errors in pediatric professional healthcare settings: A systematic review. **Country**: Germany **Funding**: None stated. **Bias**: • Time-lag bias when positive study results are published sooner than non-significant or negative results. • Confounding		**Purpose:** • Identify interventions to reduce and/or prevent drug dispensing, administration, and monitoring errors and determine the effect.	n= 1 examined dispensing errors n= 12 considered med use process and associated steps. N= 7 featured drug admin errors. N= 34 interventions of 44 total identified within 14 of 20 studies. **Demographics:** • Studies originated from 11 countries; 4 continents; majority in North America **Setting:** All studies addressed pediatric hospital settings focusing on inpatient care (n=15; 75%). **Exclusion:** • No author listed and/or abstract.	**DV1:** Substitution interventions **DV2:** Engineering controls interventions **DV3:** Administrative controls interventions **Definitions:** • ME • Dispensing error • Administration error • Monitoring error • Medication use process • Intervention	• ROBINS-I **Validity/ Reliability:** • Before the discussion, agreement was 72% (weighted k= 0.45, "fair" agreement). After discussion, complete consensus was reached.	• Mann-Whitney U-test • Cohen • Inter-quartile range • Fisher exact test	aim to reduce risk (n=4; 9%) **DV2:** Interventions of engineering control (n=7; 16%). **DV3:** Majority of interventions administrative (n= 34; 75%) (Reported significant error reduction 62%).	**Strengths**: • Hierarchy control of models enabled the classification of interventions. • Interrater reliability increased validity. **Weakness**: • The research included uncontrolled before-after studies. • Use of studies within eight yr. span excluded other reviews. **Feasibility**: Adopting interventions that substitute lower-risk options for risk-prone processes improves med safety. **Application**: Clinicians can administer

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			• Full text, not in English. • Published before 11/22/2011. • Meeting or conference abstract. • Duplicate. • Case report only. • No original data. • No human data. • No children included. • No pediatric data was provided separately. • No Mes. • No intervention • Reduce prescribing volume only • Simulation outcomes only. • Only address misdiagnosi s. **Attrition:** 0%					administrative controls alongside higher-level interventions.

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Table A2

Synthesis Table

Study (Author, year)	Aletayeb et al., 2019	Berg et al., 2021	Chongthavonsatit et al., 2021	Liang et al., 2023	Westbrook et al., 2022	Kung et al., 2021	Conn et al., 2020	Karimian et al., 2018	Eisenbach et al., 2020	Koeck et al., 2021
Design **LOE**	DCSS IV	RCT II	RCE II	MM III	SWCRCT II	QE III	RA III	RA III	CC III	SR I
Sample										
Subjects	155	-	562 P	60	4,821	5,932 MD	1,522	206	100	20
Age	Neonates	-	-	0-18 Yrs.	0-18 Yrs.	30.5 M-Age	0-16 Yrs.	0-18 Yrs.	0-12 Yrs.	0-18 Yrs.
Participants	-	93 SRN	20 EMR	-	-	13 RNs	-	-	-	-
Setting										
Pediatric Hospital	X			X	X	X	X	X	X	X
Simulation		X	X							
Interventions										
CPOE			X	X					X	X
Barcode Scanning		X		X		X			X	X
EMS	X	X		X	X				X	X
Education	X	X	X	X	X	X	X	X	X	X
eMAR		X	X	X			X	X	X	X
Bundled Interventions	X	X	X	X	X	X	X	X	X	X
Outcomes/ Themes										
Wrong Dose	X			X	X	X	X		X	
Wrong Route	X				X	X	X		X	
EMS & Education	X	X		X	X				X	X
eMAR & Education		X	X	X			X	X	X	X
Interventions on Pediatric Mes					No Change in Year 1, then 					

Key: **CC** Case Control, **CPOE** Computerized Provider Order Entry, **DCSS** Descriptive Cross-Sectional Study, **eMAR** Electronic Medical Administration Record, **EMR** Emergency Medicine Residents, **EMS** Electronic Medication System, **LOE** Level of Evidence, **M-Age** Median Age, **ME** Medication Error, **MD** Medication Doses, **MM** Mixed Methods, **P** Prescriptions, **QE** Quasi-Experimental, **RA** Retrospective Analysis, **RCE** Randomized Crossover Experimental, **RCT** Randomized Controlled Trial, **RN** Registered Nurse, **SR** Systematic Review, **SRN** Student Registered Nurse, **SWCRCT** Stepped-Wedge Cluster Randomized Controlled Trial

Appendix B

Outcomes

Table B1 Outcomes
Frequency Table for Outcome Variables

Variable	*n*	%
Name and date of birth		
Yes	8	50.00
No	8	50.00
Missing	0	0.00
Right patient		
Yes	15	93.75
No	1	6.25
Missing	0	0.00
Patient allergies and adverse drug reactions		
Yes	6	37.50
No	9	56.25
Yes/No	1	6.25
Missing	0	0.00
Updated allergies and/or discussed discrepancies with the provider		
Yes	13	81.25
No	3	18.75
Missing	0	0.00
Checked the medication against the medication order		
Yes	16	100.0
Missing	0	0.00
Medication is indicated for the patient diagnosis and there are no duplicate orders		
Yes	16	100.0
Missing	0	0.00
Checked the expiration date		
Yes	13	81.25
No	3	18.75
Missing	0	0.00
Right time and frequency		
Yes	16	100.0
Missing	0	0.00

Right route		
Yes	16	100.0
Missing	0	0.00
Checked the medication dose against the medication order and confirmed the dose		
Yes	14	87.50
No	1	6.25
Yes/No	1	6.25
Missing	0	0.00
Right to refuse		
Yes	16	100.0
Missing	0	0.00
Nurse conducts patient observations prior to administration		
Yes	16	100.0
Missing	0	0.00
Hand hygiene and uses appropriate personal protective equipment		
Yes	16	100.0
Missing	0	0.00
Aseptic technique when preparing and administering		
Yes	16	100.0
Missing	0	0.00
Correct administration technique of IV injectable line setup		
Yes	16	100.0
Missing	0	0.00
Added correct and completed additive medicine and line labels		
Yes	16	100.0
Missing	0	0.00
Confirms medication requires two nurses to check medication calculations		
Yes	15	93.75
No	1	6.25
Missing	0	0.00
Both nurses witness the preparation		
Yes	14	87.50
No	2	12.50
Missing	0	0.00
If double check required both nurses go to the bedside		
Yes	12	75.00
No	3	18.75
Yes/No	1	6.25
Missing	0	0.00
Asks the patient if they know what the medicine is for		
Yes	10	62.50
No	6	37.50

Missing	0	0.00
Witnesses the patient takes or correctly self-administers		
Yes	16	100.0
Missing	0	0.00
Documentation of medication administration		
Yes	16	100.0
Missing	0	0.00

Note. Due to rounding errors, percentages may not equal 100%.

Appendix C

Descriptive Statistics

Table C1 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Name and Date of Birth

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	5.69	4.12	8	0.50	13.00

Table C2 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Right Patient

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	8.07	9.34	15	0.50	38.00

Table C3 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Patient Allergies and Adverse Drug Reactions

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	9.50	14.18	6	0.50	38.00

Table C4 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Updated Allergies and/or Discussed Discrepancies with the Provider

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	8.19	9.82	13	0.50	38.00

Table C5 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Checking the Medication Against the Medication Order

Variable	*M*	*SD*	*n*	Min	Max
Number of years as nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C6 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Medication is Indicated for the Patient Diagnosis and There are No Duplicate Orders

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C7 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Checked the Expiration Date

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.65	9.69	13	0.50	38.00

Table C8 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Checked the Medication Dose Against the Medication Order and Confirmed the Dose

Variable	*M*	*SD*	*n*	Min	Max
Number of years as nurse					
Yes	8.32	9.64	14	0.50	38.00

Table C9 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Right Route

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C10 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Right Time and Frequency

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C11 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Right to Refuse

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C12 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Nurse Conducts Patient Observations Prior to Administration

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C13 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Hand Hygiene and Uses Appropriate Personal Protective Equipment

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C14 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Aseptic Technique when Preparing and Administering

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C15 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Correct Administration Technique of IV Injectable Line Setup

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C16 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Added Correct and Completed Additive Medicine and Line Labels

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C17 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Confirms Medication Requires 2 Nurses to Check Medication Calculations

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	8.10	9.33	15	0.50	38.00

Table C18 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Both Nurses Witness the Preparation

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.43	9.35	14	0.50	38.00

Table C19 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by If Double Check Required Both Nurses Go to the Bedside

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	9.00	10.31	12	0.50	38.00

Table C20 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Asks the Patient if They Know What the Medicine is For

Variable	*M*	*SD*	*N*	Min	Max
Number of years as a nurse					
Yes	10.15	10.98	10	0.50	38.00

Table C21 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Witnesses the Patient Takes or Correctly Self-Administers

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					
Yes	7.88	9.05	16	0.50	38.00

Table C22 Descriptive Statistics

Descriptive Statistics Table for Interval and Ratio Variables by Documentation of Medication Administration

Variable	*M*	*SD*	*n*	Min	Max
Number of years as a nurse					

Yes	7.88	9.05	16	0.50	38.00