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PREVALENCE AND DETERMINANTS OF INTRAVENOUS ADMIXTURE PREPARATION ERRORS. A PROSPECTIVE OBSERVATIONAL STUDY IN HOSPITAL

Original Research

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ABSTRACT

Background: Intravenous admixture preparation errors (IAPEs) are critical issues in healthcare, involving incompatible diluents, incorrect mixing techniques, and wrong volumes of diluents and IV fluids. These errors compromise patient safety, with significant risks of adverse effects due to the rapid bioavailability of intravenous drugs. Despite the known dangers, insight into the prevalence, determinants, and severity of these errors in hospital settings is limited, underscoring the need for targeted preventive measures to enhance IV therapy safety.

Objective: This study aimed to determine the prevalence, types, and severity of IAPEs, identify the major determinants causing these errors, and propose strategies for minimizing their occurrence in hospital settings.

Methods: A prospective observational study was conducted across three private hospitals in Islamabad. Data were collected from various wards, including inpatient, emergency, general, infectious, gastroenterology, and respiratory wards. Observations of IV admixture preparation were performed covertly to avoid altering staff behavior. A structured data collection sheet was used to record errors related to diluent selection, volume, labeling, and mixing techniques. Demographic and professional information of staff, as well as ward-specific conditions, were documented. Statistical analysis was performed using descriptive statistics to evaluate the prevalence, types, and severity of errors.

Results: Of the observed IV admixtures, 60% were prepared by nurses, while 24.6% were prepared by pharmacists. The most common errors included incorrect diluent volume (58%), incomplete mixing (44.8%), and improper labeling (65.9%). Normal saline was used in 55.2% of preparations, while 53.6% of admixtures contained powdered antibiotics. Only 41.8% of staff adhered to sterile area protocols, and 71.5% had received IV admixture preparation training. Major determinants included insufficient knowledge, lack of training, poor working conditions, and excessive patient load.

Conclusion: IAPEs are prevalent in hospital settings, largely driven by insufficient training, knowledge gaps, and suboptimal working conditions. Comprehensive training, adherence to standardized guidelines, and implementing centralized IV admixture preparation programs can significantly reduce these errors and enhance patient safety.

Keywords: Errors, Intravenous Admixtures, IV Fluids, Mixing Techniques, Patient Safety, Sterile Area, Training.

INTRODUCTION

Intravenous admixtures, sterile pharmaceuticals added to intravenous solutions for continuous infusion, play a critical role in modern clinical care. However, the preparation and administration of these medications carry significant risks due to their complex, multistep processes (1, 2). Intravenous incompatibilities, arising from the simultaneous administration of two or more medications through a single IV line or in a single solution, can lead to undesirable reactions such as precipitation, insolubility, or chemical degradation. These occurrences pose severe risks, including toxicity, reduced therapeutic efficacy, and even fatal outcomes. The immediacy and systemic effects of IV medications, coupled with their low therapeutic index and the challenges of reversing their effects once administered, make them particularly hazardous in cases of error (3).

The preparation of intravenous medications in clinical settings demands meticulous attention to detail to mitigate potential errors. These errors can include the use of incorrect drugs, improper doses, unsuitable diluents, or failures in maintaining sterility and compatibility. Incompatibilities may result from a variety of factors, such as precipitation caused by dilution, pH shifts, ionic interactions forming insoluble compounds, or the denaturation of biological components (4, 5). Alterations to IV medications, including dilution, reconstitution, or titration, can further complicate their stability and compatibility, increasing the potential for errors (6).

Reports indicate that the frequency of intravenous admixture preparation errors varies widely across studies, underscoring the widespread prevalence and clinical impact of these mistakes. Errors in dosing, concentration, and mixing techniques are alarmingly common, with detrimental errors sometimes exceeding 60% in certain clinical contexts (7). Observational studies have revealed that errors are detected in approximately one out of every five doses when bedside monitoring is utilized, with a substantial proportion of these errors involving omissions or incorrect preparation techniques. Such errors are particularly concerning given the rapid bioavailability of IV drugs, which magnifies the potential for adverse effects following improper preparation or administration (8, 9).

A thorough understanding of the determinants contributing to intravenous admixture preparation errors is essential to improving patient safety (10, 11). Factors such as inadequate training, insufficient standardization of protocols, and the inherent complexity of IV drug preparation processes have been identified as key contributors. Addressing these issues requires a systematic approach to ensuring compatibility, maintaining sterility, and standardizing preparation practices (12).

This study aims to evaluate the prevalence and determinants of intravenous admixture preparation errors, with a focus on identifying the types and severity of errors, such as those related to drug selection, dosing, diluent compatibility, and mixing techniques. By investigating the root causes of these errors, the study seeks to provide actionable insights for minimizing risks and enhancing the overall safety of intravenous medication preparation and administration.

METHODS

The study employed a prospective observational design and was conducted in multiple wards, including emergency, gastroenterology, general inpatient, surgical, and infectious disease wards, across NESOM Hospital, Shifa Hospital, and PIMS Hospital in Islamabad. The study population consisted of patients aged 14 years and older who were admitted to these wards and receiving intravenous (IV) medications. Patients from pediatrics, neonatology, oncology, renal failure, dialysis, and those receiving total parenteral preparations were excluded from the study to ensure focus on the targeted population.

Data collection was carried out through direct observation and prospective methods. To minimize observer bias and prevent any alterations in behavior due to awareness of being observed, the staff involved in IV preparation was not informed of the study's detailed purpose. Following the observation periods in each unit, nursing staff were asked to complete structured questionnaires capturing their demographic and professional characteristics, including gender, age, degree type, educational level, and experience since obtaining their first nursing diploma. Simultaneously, data on patient characteristics, such as gender, date, and the number of prescribed medications per day, were recorded. Additional factors, including the pharmaceutical form of medications, the frequency of interruptions during preparation, the time frame of administration, and the type of clinical ward, were also systematically documented.

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The sample size was calculated using Raosoft software, ensuring a 95% confidence level and a 5% margin of error. Based on these parameters, a recommended sample size of 133 participants was determined. The collected data were analyzed using SPSS (Statistical Package for the Social Sciences) software to ensure accurate and reliable statistical evaluation.

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Ethical approval for the study was obtained from the Institutional Review Board of Ibadat International University Islamabad, with reference number IRB-IIUI-FAHS/PHM/1045-2135, dated October 2, 2023. The study adhered to ethical standards throughout its execution.

RESULTS

The preparation of intravenous (IV) admixtures was predominantly carried out by nurses, accounting for 60.4% of preparations, followed by pharmacists at 24.6%. A smaller proportion was prepared by non-technical staff (9.0%), while doctors contributed to 5.2% of preparations. Experience levels among staff involved in IV admixture preparation revealed that 51.5% had over five years of experience, 37.3% had between one to five years, and 10.4% had less than one year. Regarding qualifications, 30.6% held degrees, 21.6% were certified IV admixture experts, 12.7% had secondary-level education, and 7% had primary-level qualifications. Knowledge of USP 797 guidelines was present in 56.7% of staff, while 71.5% had received relevant training for IV admixture preparation. Despite this, adherence to protocols such as laminar flow hood usage and proper labeling was limited, with only 41.8% and 30.4% compliance, respectively.

The study also analyzed the types of IV admixtures and diluents used. Antibiotics were the most frequently prepared admixtures at 53.6%, followed by anti-hypertensives (17.3%), steroids (12%), anti-inflammatory agents (8.3%), and acidity reducers (6.8%). Most medications (97.8%) were prepared according to the prescribed strength. Diluents commonly used included normal saline (55.2%), sterile water (40.3%), Ringer lactate (7%), and dextrose (3%). However, only 35.5% of diluents were compatible with the drugs, and 41% of diluent volumes were accurate. Similarly, while 64.2% of admixtures contained a single drug, 32.1% contained two drugs, and 3% had more than two drugs. Mixing techniques varied, with vigorous mixing observed in 44.8% of cases, gentle mixing in 35.8%, and irregular mixing in 6%.

Errors were prevalent across various steps of preparation and administration. Errors were highest in emergency wards at 23.1%, followed by gastroenterology (14.9%) and general wards (12.7%). According to NCC MERP classifications, 70% of errors were type C (no harm), while 15% were type D (required monitoring). Harmful errors included 10% type E, 4% type F, and 1% type H, underscoring the need for strict adherence to protocols and improved safety measures in IV admixture preparation and administration.

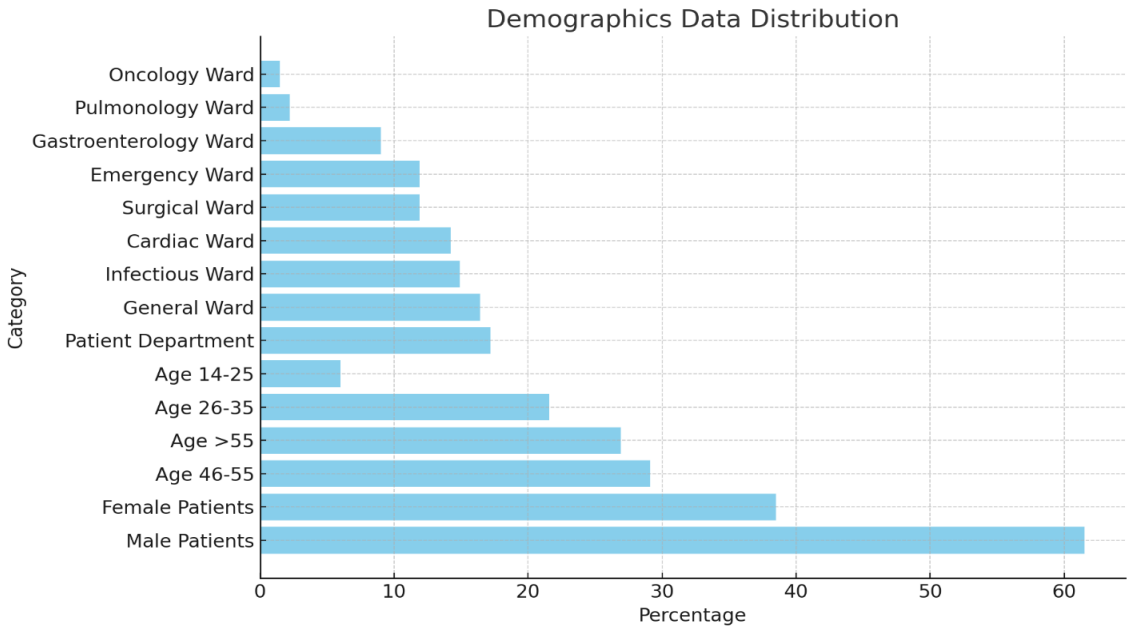

Figure 1 Demographics Data Distribution

The demographics data revealed that 61.5% of the observed patients were male and 38.5% were female. The largest age group was 46–55 years (29.1%), followed by patients over 55 years (26.9%), 26–35 years (21.6%), and 14–25 years (6.0%). Most data were collected from the Patient Department (17.2%), General Ward (16.4%), Infectious Ward (14.9%), and Cardiac Ward (14.2%). Surgical and Emergency Wards each contributed 11.9%, while the Gastroenterology Ward provided 9.0%, Pulmonology Ward 2.2%, and Oncology Ward 1.5% of the total data.

Table 01: Severity of IAPE's

Sr. No	Variables	Frequency	Percentage
	Error C	93	69.4
	Error D	20	14.9
	Error E	13	9.7
	Error F	5	3.7
	Error H	2	1.5
	Total	133	100

The severity of intravenous admixture preparation errors (IAPEs) revealed that the majority were classified as Error C, accounting for 69.4% (93 cases), indicating errors that occurred but did not cause harm. Error D, involving errors requiring monitoring or intervention to prevent harm, represented 14.9% (20 cases). More severe errors included Error E, associated with temporary harm, which accounted for 9.7% (13 cases), and Error F, involving prolonged harm, observed in 3.7% (5 cases). The most critical errors, classified as Error H, which result in life-threatening consequences, accounted for 1.5% (2 cases). In total, 133 errors were recorded, emphasizing the need for enhanced preventive measures to minimize these occurrences and ensure patient safety.

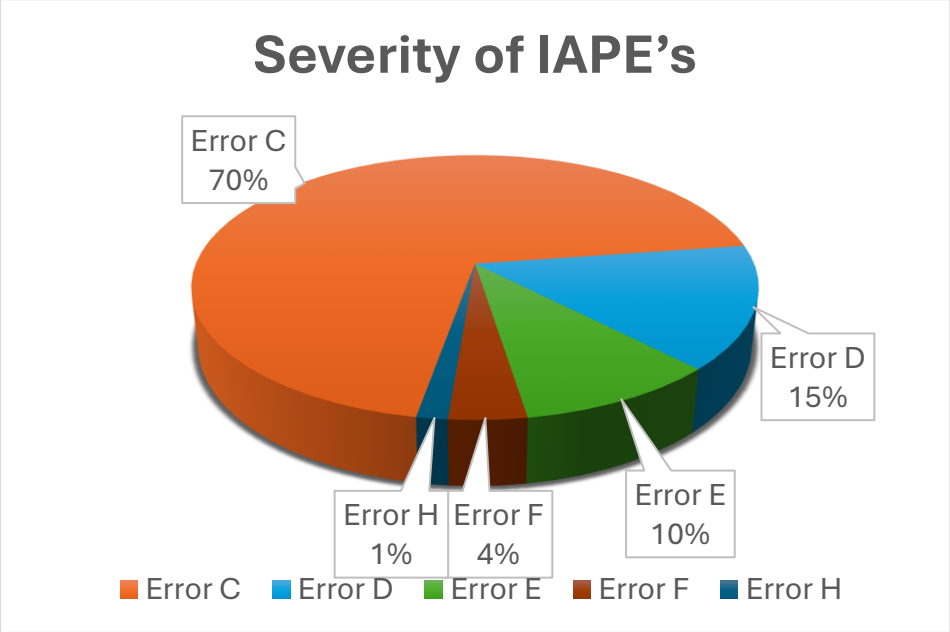

Figure 2 Figure 2 Severity of IAPE's

No error (category A); error, no harm (category B to D); error, harm (category E to H); and error, death (category I). C: an error occurred that reached the patient but did not cause patient harm; D: an error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm; E: an error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention; F: an error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization; H: an error occurred that required intervention necessary to sustain life.

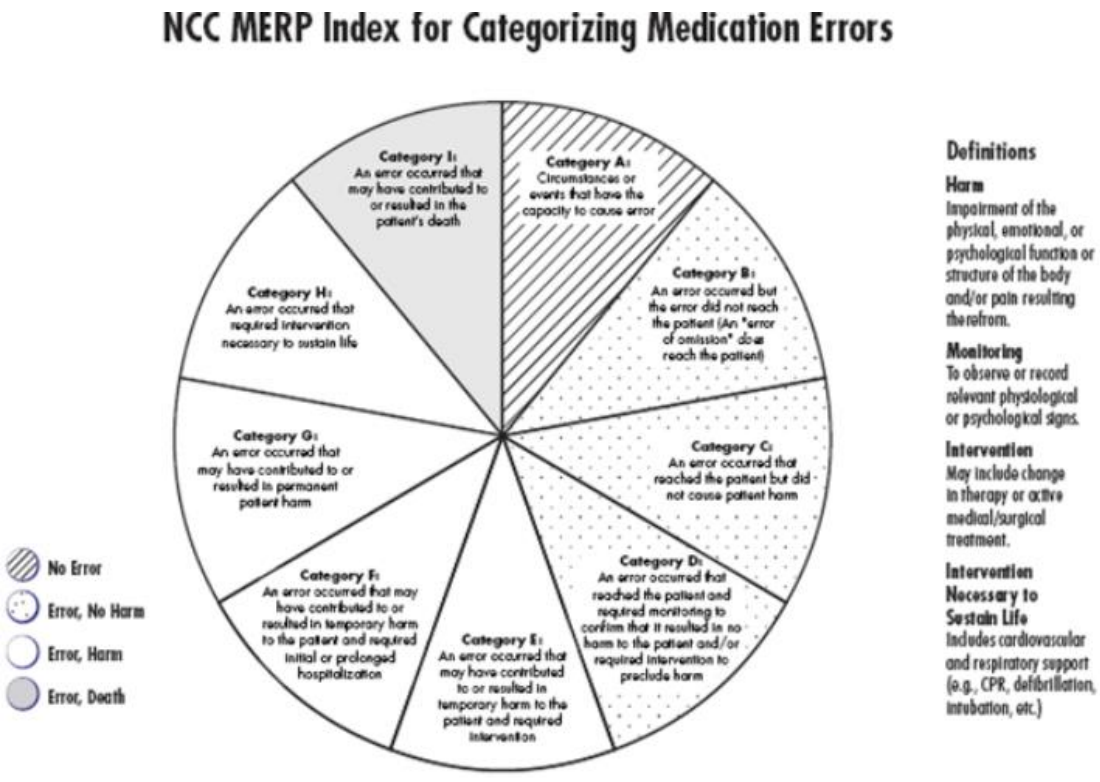

Figure 3 NCC MERP Classification

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DISCUSSIONS

Intravenous admixtures are sterile preparations that require careful handling in sterile environments to minimize the risk of contamination and errors. Despite these requirements, errors in preparation remain a significant concern, particularly those related to incorrect diluents, incompatible combinations, inappropriate volumes, and incomplete mixing (13, 14). These errors not only compromise the physical and chemical compatibility of the admixture but also pose serious risks to patient safety. Data collected from six wards across three hospitals (PIMS, NESCOM, and Shifa Hospital) highlighted that the most frequently observed errors involved incomplete mixing and incorrect volumes of diluents and infusion fluids. Additionally, the findings demonstrated a lack of adherence to USP 797 guidelines, including inadequate knowledge among staff, absence of proper sterile areas, and insufficient use of laminar flow hoods. These factors collectively contributed to the prevalence of errors in IV admixture preparation (15, 16).

The study further identified systemic challenges, such as insufficient training and the absence of standardized protocols, which significantly impacted the quality of IV admixture preparation. Approximately 60% of admixtures were prepared by nurses, while pharmacists accounted for only 24.6%. The workload and time constraints faced by nurses, especially during critical periods such as shift changes, lunch breaks, and ward rounds, often led to rushed preparation processes and increased susceptibility to errors (17). This aligns with findings from previous research, where interruptions during preparation were highlighted as a major contributor to medication errors. Interruptions force healthcare professionals to divide their attention between tasks, potentially leading to errors in preparation and administration. Furthermore, the results revealed that 58% of admixtures involved incorrect volumes of diluents, and 53% of the admixtures contained powdered antibiotics, emphasizing the need for greater attention to preparation techniques and standardization (18, 19).

While the study provided valuable insights into the types and causes of IV admixture preparation errors, it was not without limitations. The use of disguised observation, although a gold standard in error detection, introduced the potential for observer bias (18). Variations in sample size, data collection methods, and analytical techniques also posed challenges to generalizability. Additionally, the inclusion of new questions, such as staff adherence to USP guidelines and proper sterile area practices, introduced variables that were not addressed in previous studies, limiting direct comparisons (20, 21). Despite these limitations, the study highlighted critical gaps in knowledge, training, and infrastructure, offering a foundation for targeted interventions to improve the safety and quality of IV admixture preparation in clinical practice (22).

A recent study conducted by Jessurun et al. (2021) highlighted the prevalence and determinants of intravenous admixture preparation errors (IAPEs) in a Dutch university hospital. This prospective observational study revealed that 59.8% of admixtures prepared by nursing staff contained at least one IAPE. The most frequent errors were associated with improper preparation techniques and incorrect infusion fluid volumes, while 11.1% of the errors were deemed potentially harmful. Key factors associated with these errors included multistep versus single-step preparations, interruptions during preparation, and specific time windows, such as increased error rates between 2 p.m. and 6 p.m. These findings emphasized that working conditions, preparation complexity, and ward-specific workflows significantly influence the occurrence of IAPEs. The study concluded that targeted interventions, such as standardization of preparation protocols, enhanced training programs, and minimizing interruptions, could significantly reduce these errors and improve patient safety (23).

CONCLUSION

The study highlighted that intravenous admixture preparation errors (IAPEs) are prevalent in hospital settings and pose significant risks to patient safety, particularly when multiple drugs are combined in the same infusion bag. It identified IV admixture incompatibility as a critical concern and provided insights into key determinants contributing to these errors. These findings emphasize the importance of targeted interventions, such as staff education, adherence to standardized guidelines like USP 797, continuous monitoring, and improved compatibility testing, to mitigate risks and ensure the safe administration of intravenous medications. Importantly, these measures are achievable even within resource-limited settings, underscoring the potential for meaningful improvements in patient care through practical and cost-effective strategies. By addressing the root causes of IAPEs, healthcare systems can enhance the quality and safety of IV therapy and protect patients from avoidable harm.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Ayesha Sana	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muhammad Hamza	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Ammar Awan	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Bilal	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Najam-us-Sahar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Kashif Iqbal	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Robaica Khan	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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