

Medication Errors in Intravenous Drug Preparation and Administration: A Brief Review

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Abstract

Medication errors in intravenous drug administration can be defined as any mistakes in the preparation, dispensing and administration of these drugs. Medication errors can be classified based on the stage of intravenous therapy in which the error occurs (pre-preparation phase, preparation of medication by nurse, drug labelling, and drug administration). In intravenously administered medications, errors may have particularly serious consequences.

Medication errors are more likely to be recorded during the morning hours. Inappropriate speed of administration was found to be the most common type of error in intravenously administered drugs, with slow bolus injection being the route of administration associated with the most risk. Greater safety of the medication process can be achieved by eliminating risk factors and by using different strategies to detect errors. In addition to eliminating the most dangerous human risk factors (work overload of nurses, their fatigue, and general lack of personnel), the use of various supportive technologies, such as computerized prescription of drugs, barcode scanning, and the use of electronic infusion pumps, effectively decreases the risk of medication errors.

Key words:

Medication errors; Intravenous drugs; Classification of medication errors; Nursing management; Patient safety

Introduction

The use of medications can be a benefit for patients only if the principles of their safe use are followed by both health care professionals and patients. Moreover, any use of a drug entails a risk of medication error. These errors can occur in any phase of drug management: prescription, preparation, dispensing, or administration of the drug. Adverse events associated with the use of drugs can have serious human and economic consequences [1]. Errors that occur in healthcare systems have been reported as the seventh most common cause of death [2]. A study by Lisby et al. found that medication errors and adverse drug reactions led to disability or death of patients in 6.5% of hospitalizations [3]. However, most medication errors have not been a result of reckless behavior of health care providers, but rather a result of the speed and complexity of medication-use cycle [4,5]. Intravenously administered drugs exhibit the highest risk of medication errors, particularly for their complicated preparation [6,7]. Consequences of the mistakes that occur during the administration of these drugs may also be more serious than in drugs delivered by other routes of administration. One of the largest mixed-methodology studies using a 5-year review of 73,769 intravenous-related medication errors from the US National Medication Error Reporting Program suggested that between 3% and 5% of these errors were harmful [8]. The purpose of this publication is to provide a brief review of the medication errors in intravenous (IV) drugs, in different settings and patient populations. In recent years, no summary overview of current knowledge, that could reduce the risk of drug errors in parenteral

drugs have been published. We have intended to summarize the most important information on the topic useful for nurses routinely working with parenterally administered drugs.

Classification of Medication Errors in Intravenous Drugs

The best way to prevent medication errors is to understand their causes. For that purpose, the use of correct classification of errors has been useful. Classification systems may be contextual, modal, or psychological. Contextual classification deals with a specific time, place, drugs, and people involved in the event. Modal classification examines the processes by which the error occurred. Psychological classification focuses on man and his description of the event [9]. Medication errors are usually divided into those based on the onset, underlying cause, medication error index, severity, and psychological approach [10].

Classification based on the onset

Medication errors can be classified as active or latent errors. Active errors have an immediate effect. Latent errors have delayed effects, are easily identifiable and thus can be corrected before it recurs [11].

Classification based on the underlying cause

Based on their cause, medication errors can be classified as follows: omission, wrong dose, an unordered error (this error occurs when a patient receives a medication for which the physician did not write an order), wrong dosage form, wrong time, wrong route, deteriorated drug (compromise of physical or chemical integrity of medication

dosage form), wrong rate of administration, wrong administration technique, wrong dose preparation and extra dose error [12].

Classification based on the severity

Based on their severity, medication errors may be classified as a category A, B and C.

- **Category A** - Potentially serious error that can cause permanent harm to patient, may increase hospitalization or need of additional treatment.
- **Category B** - Clinically significant error can increase need for patient monitoring.
- **Category C** - Clinically non-significant error that does not harm the patient [13].

Classification based on the medication error index

The National Coordinating Council for Medication Error Reporting and Prevention adopted a Medication Error Index that classifies an error according to the severity of the outcome in July 1996. It is hoped that the index will help health care practitioners and institutions to track medication errors in a consistent, systematic manner. The index considers factors such as whether the error reached the patient and, if the patient was harmed, and to what degree. The Council encourages the use of the index in all health care delivery settings and by researchers and vendors of medication error tracking software. This medication error index is shown in Table 1 [14].

Error category	Characteristics of error
Category A	Circumstances or events that have the capacity to cause error
Category B	An error occurred but the error did not reach the patient (an "error of omission" does reach the patient)
Category C	An error occurred that reached the patient but did not cause patient harm
Category D	An error occurred that reached the patient that required monitoring to confirm that it resulted in no harm to the patient and/ or required intervention to preclude harm
Category E	An error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention
Category F	An error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization
Category G	An error occurred that may have contributed to or resulted in permanent patient harm
Category H	An error occurred that required intervention necessary to sustain life
Category I	An error occurred that may have contributed to or resulted in the patient's death

Table 1: Index for categorizing medication errors according to National Coordinating Council for Medication Error Reporting and Prevention [14]

Medication errors in drugs for intravenous administration are usually classified according to the phases of intravenous therapy [15]. The types of errors in these individual phases are shown in Table 2. Medication errors in intravenous drugs may also occur due to not

complying with hospital standards, guidelines, or recommendations of the drug manufacturer [7].

Phase of therapy	Type of error
Errors in pre-preparation phase	wrong medication non-aseptic methods in preparation and administration of medications (hands not washed, preparation surface not cleaned, vials and ports not disinfected with alcohol swabs, touched sterile areas and etc.)
Errors in preparation of medication	incorrect calculation of drug concentration wrong diluent for preparation of intravenous drugs insufficient stirring or dissolution of active agent wrong volume of medication or infusion
Errors in labelling of medication	wrong, partial, or unreadable label of medication
Errors in administration of medication	fast rates of drug administration omission of dose or extra dose wrong administration technique wrong patient, wrong time of administration, or wrong drug non-aseptic administration

Table 2: Types of medication errors in various phases of pharmacotherapy [10].

Errors in pre-preparation phase

Wrong choice of medication is the most serious possible error, usually occurring as a result of inattention or hard-to-read medical prescription. Violation of the basic principles of aseptic preparation and administration of intravenous drugs is also a common source of possible errors in this phase. Aseptic methods in this phase include cleaning the preparation area, washing hands or wearing sterile gloves, disinfecting vials, etc.

Errors in preparation

The dose of the drug should be properly calculated prior to the preparation itself to avoid inaccuracies in the dose or volume infused. The use of inappropriate diluent may cause incomplete dissolving of the solution, precipitation of the drug and may also lead to reduced stability or even reduced effect. Of course, not all available diluents (the most common being water for injection or normal saline) are suitable for dilution of all intravenous drugs. Common medical documentation used at inpatient wards rarely specifies the diluent of intravenous drugs. Nurses need to know the manufacturer's recommended procedures for individual drugs and may also consult this issue with the pharmacy. Solutions for intravenous administration require proper dissolution that should be checked by nurses before each individual administration.

Errors in labelling

All drugs prepared for parenteral administration should be correctly labelled. Drugs with the highest risk are those not administered immediately after preparation and the risk increases significantly if their labelling is not sufficiently clear.

Errors in administration of medication

The rate of administration of the drug should be adjusted correctly. However, the prescribed rate of infusion may not always be followed

by the nursing staff and the administration rate is sometimes accelerated intentionally. Incorrect administration time has usually been defined as the deviation of more than 30 minutes from the planned time, but even slighter differences can also lead to undesired effects. Too rapid administration of the drug can cause many serious complications, with pain in the site of injection or phlebitis being the most frequent. If the nurse notices turbidity, crystallization, discoloration of the drug or other signs of contamination and incompatibilities, the infusion must be immediately stopped. The full concentration should be given during intravenous drug administration to prevent any avoidable mistake in the drug dose. All intravenous lines should be checked prior to administration. They should be intact and the drug passage should be without any blockage [15].

Recent Observation Studies of Medication Errors in Intravenous Drug Administration

Many published studies dealt with the issue of medication errors. Comparing the results of these studies is difficult because they use many different research methodologies. Individual studies vary in the very definition of medication error that they use. Still, the results of these studies may be useful in preventing medication errors in everyday nursing practice. In the next section we will try to emphasize only some of the most interesting results of recent studies.

An interesting example of a study dealing with the frequency of errors in preparation and administration of intravenous drugs is the study by Ong and Subasyini published in 2013 [15]. The main result of this paper was the finding that errors, including the delivery of the wrong drug, most often occurred during the morning drug administration (at 8 a.m.). The probable cause was a lack of time for preparation and administration of the medications during the morning hours caused by the need for more nursing interventions at that time. As in other researches, the most common error was the wrong rate of administration [7,16]. This type of error is more common in drugs given by slow (3-5 minutes) intravenous bolus. For such drugs, the authors recommended to use an alternative administration method, such as short infusion. This method does not require the presence of a nurse at the bedside throughout the medication administration process. Not surprisingly, the authors found that the higher was the number of drugs administered at the same time, the greater was the risk of medication error [15].

Another recent research examined the frequency, the type of medication errors as well as the relationship between the incidence of mistakes and experience of the nursing staff. The number of errors was found to be significantly dependent on the experience of nurses. Six years' experience may reduce the risk of error by 11-19%. The incidence of medication errors was higher in the administration of bolus doses than in the case of infusions [6].

A prospective ethnographic study using disguised observation, published by Taxis and Barber, dealt with the incidence of medication errors, their clinical significance, and the phases of the preparation and administration of the drug in which the error occurred. A total of 430 drugs were prepared and administered during this study. Medication errors were found in 212 of them. The authors identified 249 errors, 32 of which were found in the phase of preparation, 155 during drug administration, and 25 in both the phases [17].

Valentin et al. conducted an international observational prospective study with self-reporting by the nursing staff. It included 113 intensive care units in 27 countries. Its main objective was to assess the

frequency, characteristics, contributing factors, and preventive measures of administration errors in parenteral medication on a multinational level. A total of 861 medication errors affecting 441 patients were found. Three quarters of these errors were classified as errors of omission. Administration of the drug at a wrong time was the most frequent type of error (386 of 861). With respect to the type of administration, 9% of medication errors occurred during intravenous bolus administrations, 6% during continuous intravenous administrations, and 6% during subcutaneous administrations. The most frequent medication errors occurred during the administration of antimicrobial drugs and sedatives or analgesics. Twelve patients (0.9%) died or experienced permanent harm because of medication errors at the administration stage. Medication errors in intravenous drugs are common and serious problems of pharmacotherapy, particularly in intensive care units. The occurrence of these errors increases with the increasing complexity of care in critically ill patients [18].

A study performed in Tehran dealt with the frequency of medication errors that occurred during the preparation and administration of intravenous drugs in an intensive care unit. A total of 524 preparations and administrations of intravenous drugs were followed. The calculated number of opportunities for error was 4,040. The real incidence of medication errors was 380 (9.4%). Among all the errors made, 66.4% and 33.4% were related to the administration and preparation processes, respectively. Inappropriate velocity of bolus administration (43.4%) was the most frequent error, followed by wrong infusion rate (23%), wrong dose or diluent calculation (20.1%), and inappropriate diluents (11.2%). No significant correlation was found between the incidence of error and the nurses' age, sex, qualification, work experience, marital status, and type of working contract (permanent or temporary) in this study [19].

Another Tehran study also examined the incidence of medication errors in intravenous drugs. During the observation period, 357 drugs were prepared and administered. Most of the errors occurred in the process of administration of the drug (wrong administration rate of the drug bolus). Furthermore, it was found that most medication errors were made during the preparation and administration of metronidazole and ranitidine. There was no significant correlation between error rates and demographic characteristics of nurses in this study [20].

Prevention of Medication Errors in Intravenous Drugs

Optimal safety of the medication process can be achieved by eliminating the risk factors and using strategies to detect errors. Effective strategies include computerized prescription of drugs, barcode technology of labelling, and the maximum possible use of electronic intravenous infusion pumps.

Computerized prescribing allows physicians to enter the prescription of drugs in a computerized system. The system monitors the patient's allergies, warns of potential drug interactions, recommends the dosage or suggests suitable drugs for patients with specific diseases. Barcode technology has been used in conjunction with computerized prescription system, wherein each drug has its specific code [2,21,22]. The nurse scans the code from the label of the drug as well as her and the patient's personal codes into a computer that automatically documents administration of the drug [23]. According to the data published, errors can be reduced by 60% [2]. Intravenous infusion pumps, computerized prescribing, and barcode

technology enable setting the correct speed of parenteral administration and the correct dose of the drug [2].

Determination of risk factors is important in the prevention of medication errors. These risk factors include work overload of nurses, lack of staff, inadequate tools and equipment, tiredness, and inexperience of nurses. Night duties and long work shifts disrupt sleep and biological rhythms, leading to lack of sleep, depressed mood, decreased attention and performance, and disruption of morale and motivation. All these factors contribute to the occurrence of medication errors. The most important risk factors are workload and inexperience of nurses. Many years of experience in nursing and adequate rest can reduce the risks during the nursing process. The staff is often less able to detect errors when its arousal level is low. It is important to improve working conditions so that health care professionals can detect errors before patients are harmed [24].

In order to make the strategies to reduce the risk of medication errors effective, one must also determine which stage of preparation and administration of intravenous drugs is most likely to pose a risk of error. Such a research was performed by McDowell et al. using a systematic review and random-effects Bayesian conditional independence modelling [25]. Table 3 shows the probability of error at each stage of intravenous pharmacotherapy found in their study. Reduction in the number of steps needed in intravenous therapy, improvement of staff training, and separate storage of vials with different doses substantially reduce the probability of errors. Some studies support the use of prefilled syringes or closed systems to reduce the risk of errors (by omitting the dilution phase). For example, in a randomized trial by Adapa et al., medication errors were 17.0 times less likely when pre-filled syringes were used [26]. However, high costs and increased storage requirements are the major limiting disadvantages of this strategy.

Stage	Type of error	Median (%)
1	Error in obtaining drug	5.34
2	Error in obtaining diluent	6.78
3	Error in reconstituting drug and diluent	31
4	Error in checking patient's identity	0.07
5	Error in checking for patient allergies	15.1
6	Error in checking route of drug administration	0.5
7	Error in checking drug dose	4.11
8	Error in checking patency of peripheral venous catheter	4.51
9	Error in expelling air from syringe	1
10	Error in administering drug	21.7
11	Error in flushing of peripheral venous catheter	5.5
12	Error in signing prescription chart	5.34
0	Omission error	3.45

Table 3: Probabilities of errors (as percentages) at each stage of intravenous drug administration. Adapted from McDowell et al. [17].

Conclusion

Intravenous medications are pharmaceutical preparations having the highest risk of possible medication errors. These drugs are typically associated with complicated preparation, administration, and monitoring. Errors in their use can have serious consequences for both the patient and health care providers. Inappropriate speed of administration of the drug was found to be the most common type of medication error in intravenous drugs. However, it is difficult to compare the results of different studies because of their varying research methods. Medication errors in intravenous administration can be prevented by both eliminating human risk factors (work overload of nurses, lack of personnel, fatigue) and using various supportive technologies (computerized prescription of drugs, barcode scanning, intravenous infusion pumps).

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