ORIGINAL ARTICLE

Medication Errors in Intravenous Drug Preparation and Administration

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SUMMARY

Medications given via the intravenous (IV) route provide rapid drug delivery to the body. IV therapy is a complex process requiring proper drug preparation before administration to the patients. Therefore, errors occurring at any stage can cause harmful clinical outcomes to the patients, which may lead to morbidity and mortality. This was a prospective observational study with the objectives to determine whether medication errors occur in IV drug preparation and administration in Selayang Hospital, determining the associated factors and identifying the strategies in reducing these medication errors.

341 (97.7%) errors were identified during observation of total 349 IV drug preparations and administrations. The most common errors include the vial tap not swabbed during pre-preparation and injecting bolus doses faster than the recommended administration rate. There was one incident of wrong drug attempted. Errors were significantly more likely to occur during administration time at 8.00am and when bolus drugs were given. Errors could be reduced by having proper guidelines on IV procedures, more common use of IV infusion control devices and by giving full concentration during the process. Awareness among the staff nurses and training needs should be addressed to reduce the rate of medication errors. Standard IV procedures should be abided and this needs the cooperation and active roles from all healthcare professionals as well as the staff nurses.

KEY WORDS:
Intravenous; medication errors; injection; administration; diluent

INTRODUCTION

Intravenous (IV) medication is administered directly into a patient's vein, thus initiating a rapid systemic response. It is a complex process usually requiring the preparation in the clinical areas before administration to the patient. Therefore, errors occurring at any stage during preparation and administration can cause serious adverse drug events such as thrombus formation, severe hypersensitivity reactions and infection, which may lead to morbidity and mortality [1,2]. It is thus important that medication errors be monitored so that similar incidents can be prevented in the future [3].

It was reported that up to 80% of hospitalized patients receive IV therapy at some point during their admission [4,5]. Studies have found that errors occurred in almost half the drug preparations and administrations [4,6,7]. Reasons for these errors include equipment, communication or personal problems; lack of training, experience and knowledge; and faults in the systems; [8]. In the United States (US), 60% of serious and life-threatening medication errors in general inpatients involved IV drugs [9]. In United Kingdom (UK), about 56% of errors involved IV drugs [10]. In pediatric patients, 54% of potential adverse drug events due to medication errors involved IV drugs [11]. It was reported that although relatively few medications are administered intravenously in the hospital setting, IV drugs account for the majority of medication errors (in number and degree of potential harm to patients) [12].

In general, medication errors are the 8th leading cause of death in the US, with the number of deaths exceeding those associated with motor vehicle accidents, breast cancer, or AIDS (Acquired Immune Deficiency Syndrome). It was shown that medication errors represent the largest single cause of errors in the hospital setting, accounting for more than 7,000 deaths annually, more than deaths resulting from workplace injuries [13].

To our knowledge, there has not been any study done or published on the medication errors in IV drug preparation and administration in the local setting. Therefore, the purpose of this study was to determine whether medication errors occur in IV drug preparation and administration in Selayang Hospital (HospSel) and how extensive was the occurrence by using the observation method, determining the contributing factors as well as identifying the strategies in reducing these errors, thus developing safe IV practice. Preventing IV medication errors are continuously stressed in various literatures for their significant reduction in morbidity and mortality and this study further urges the healthcare professionals as well as the staff nurses to put this evidence into practice.

MATERIALS AND METHODS

This was a prospective observational study conducted in a tertiary care hospital, HospSel, Malaysia. It involved a direct observation of the preparation and administration of IV drugs made by a single observer.

The study population included any IV drugs which were prepared and administered by the staff nurses to the patients. The population was chosen from all the 34 wards in the hospital which were classified into 28 general and 6 acute wards (including emergency, intensive care and labour

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units). Cytotoxic medication and total parenteral nutrition which are prepared centrally by the pharmacy department were excluded to prevent bias due to differing standards of care. Observation of a sample preparation without the administration or vice versa was also excluded.

The sampling frame was between December 2006 to March 2007, with the observer present in the wards either between 7.30am and 9.00am, 11.00am and 1.00pm, or 3.30pm and 4.30pm, as these were the right times to observe the IV drug preparation for the next administration at 8.00am, 12.00pm and 4.00pm, respectively. In order to maximize data retrieval, the time for the routine IV drug preparation and administration in each ward was identified earlier.

A total of 349 samples were obtained. Selection was based on the willingness of staff nurses to participate without any attempt at selecting a representative sample. No observation was made in 9 wards as IV drugs were either rarely used or the IV administration time was unpredictable, thus no data were collected. These include psychiatric, eye, maternity, and microsurgery wards; labour and emergency units.

A data collection form based on the written IV therapy procedures was prepared to record all actions taken from the time the IV drug was prepared to the time it was delivered to patients. The following information were obtained at different stages of observation and deviations from the standard are considered as an error:

Pre-Preparation
- Whether the right drug was chosen;
- Whether the aseptic method was used (hands washed, preparation surface cleaned, vials and additive ports disinfected with alcohol swabs, sterile areas not touched).

Preparation
- Whether the right diluent or volume (compatibilities to achieve the right concentration) was used;
- Whether the preparation was stable for administration to the patient;
- Whether the preparation was mixed properly;
- Whether the preparation dose or infusion volume was correct;
- Whether the preparation was duplicated or omitted.

Labelling
- Whether the labelling was complete and correct (identification of patient, drug, dose and time of preparation).

Administration
- Whether the preparation was delivered to the right patient, at the right time through the right route (incorrect administration time is defined as the deviation of more than 30 minutes from the planned time);
- Whether the rate and technique (bolus or infusion, alcohol swab) were correct.

The resources [14,15,16,17] and product leaflets were used as the reference regarding IV drug preparation, method of administration, stability for diluted or undiluted solution and/or reconstituted solution, compatibility and special notes for each particular drug.

The observational method was preferred over self-reporting and questionnaire survey of medication errors as it has been shown to provide the most reliable data. It was found that the observation of nurses during drug administration at a UK hospital did not significantly affect the administration errors; nor did tactful interventions made by the observers to prevent serious errors. However, concerns about the validity and reliability of observational methods for identifying medication administration errors may be unfounded [18].

The observation was carried out on weekdays except public holidays. Information about the study objective was shared with all the staff in each ward. However, the word 'error' was avoided. The results of the study were then fed back to the participating staff nurses. All staff nurses and sisters were made aware that the study aimed to identify strategies in reducing medication errors in IV drug preparation and administration and that the study did not intend to assess individual clinical practices or standards of care.

We defined an IV medication error as a deviation in the preparation or administration of a medicine from a doctor's legal prescription, reference books, or the manufacturer's instructions. The clinical appropriateness of the prescription and the potential clinical outcomes resulting from the observed medication error were beyond the scope of this study. Medication errors recorded can therefore be regarded as process errors – for example, failure to label prepared products that were not used immediately and deviations of more than 30 minutes from the planned administration time were considered as errors.

The observational data were entered into computer software spreadsheet applications and analyzed using the Statistical Package for the Social Sciences version 13.0 software (SPSS Inc., Chicago IL, USA). The magnitude of the medication errors was measurable by using descriptive statistics. Rate of error was used as an indicator to measure the problem and a standard of 0% is set. The data were tabulated and presented in the graphical form using Microsoft Excel and Word. The assessment of factors associated with the medication errors was done using bivariate analysis of chi-square χ^2, where > 20% of the cells involved expected values of < 5, a 2-tailed Fisher's Exact Test, FET probability was reported. A p value of < 0.05 was used to represent statistical significance.

RESULTS

A total of 349 samples were observed and collected. Majority of the samples, (n=240, 68.8%) were observed for the preparation and administration at 8.00am as planned in the specific wards. 91 (26.1%) were at 12.00pm, followed by 18 (5.2%) at 4.00pm. 341 (97.7%) samples having at least one medication error were identified. Pre-preparation errors occurred in 311 samples (91.2%), preparation errors in 112 samples (32.8%), labelling errors in 11 samples (3.2%) and administration errors in 302 samples (88.6%).

Errors in Pre-Preparation (N=311)
There was an incident (0.32%) whereby a wrong drug was attempted to be given to a patient. The patient was supposedly to be given IV meropenem but IV Tienam® was taken instead for preparation. The observer has checked the prescription to confirm the medication and has intervened thereafter. It was found that the IV Tienam® was confused with IV meropenem.

The area for 29 samples (9.32%) was not cleaned thoroughly before preparation. Special trolley for IV drug preparation was not used but was done on a narrow and messy area, filled with unnecessary items. Empty vials or drug packages or boxes were left on the preparation area and were not disposed of, thus causing an insufficient space for drug preparation.

It was observed that neither the hands were washed nor sterile gloves were worn in 81 samples (26%) before preparation. Majority of the drug vial taps or the ampoules were not swabbed either with alcohol swab or cotton balls (n=307, 98.7%). The vial covers were just removed and the taps left unswabbed or the ampoules were broken without swabbing first.

All windows in the preparation area were closed.

Errors in Preparation (N=112)
Wrong diluent was used for one drug (pantoprazole, Controloc®) during the observation. It should be diluted with 10ml physiological NaCl solution as instructed in the product leaflet but 10ml water for injection (WFI) was used instead. 61 samples (54.5%) were diluted with inappropriate amount. Of these 61 samples, Augmentin® accounted for the most errors (n=25), followed by Tienam® in 8 samples and C-penicillin in 5 samples.

Ranitidine accounted for 95% (19, N=20) of the errors of 'wrong because of no dilution' whereas promethazine accounted for 5%. These drugs are supposedly to be diluted prior to administration but these drugs were to the patients as bolus doses without dilution.

A total of 9 drugs were expired or became unstable after dilution prior to administration. These were 5 Augmentin®, 1 amikacin, 1 cloxacillin, 1 C-penicillin and 1 Tazocin®. The drugs were initially diluted but left unattended and exceeded the stability time between dilution and administration. For instance, Augmentin® is to be administered within 20 minutes after dilution but was not done so.

There were 22 events whereby the drugs were not properly mixed after the diluents were added for reconstitution. There were powder clumps and the granules were not uniformly mixed. These were Tienam® (n=7); cefoperazone and cloxacillin, (n=4) respectively; Unasyn® (n=3); cefotaxime, cefuroxime, C-penicillin and Sulperazon®, (n=1) respectively.

For the assessment of 'wrong dose or infusion volume' which occurred in 16 samples, inappropriate amount of drug syringed out from the vials or ampoules were considered as errors including any spillage or leaks. For example, the syringe plunger was accidentally overpressed while removing the air thereby a fraction of the drug solution was spilled out; or the patency of the IV peripheral lines was not checked, thus some of the drug leaked out from the loosen cannula during administration. The drugs were cloxacillin and ranitidine, (n=3), respectively; ceftazidime and Tienam®, (n=2), respectively; omeprazole, phenytoin, piracetam, Sulperazon®, tramadol and tranexamic acid, (n=1), respectively.

No dose duplication or omission was observed during the data collection period.

Errors in Labelling (N=11)
Majority of the drugs were prepared and administered promptly before preparing the next drug, thus the labelling error rates were low. When the stability time between preparation and administration is a concern, especially drugs like Augmentin®, amikacin, cloxacillin, C-penicillin and Tazocin®, the label of preparation time is important. 4 samples without such label were observed (metronidazole, n=3 and piracetam, n=1). These drugs were initially prepared but left aside while waiting for the IV lines to be changed or the patients were not in the ward as they went for some procedures like ultrasound or dialysis.

Label on the diluents which have been opened earlier, was absent or incomplete in 8 samples. The preparations involved include cefoperazone, (n=3); Sulperazon®, (n=2); and cefotaxime, piracetam and Tienam®, (n=1), respectively.

Errors in Administration (N=302)
127 samples (42.1%) were not administered at the time as planned in the wards. There were 59 samples (19.5%) encountered 'wrong administration technique' which referred to either the rubber bung of the injection site was not swabbed before administration or a bolus drug dose was administered as infusion, and vice versa. Wrong administration rate was the most common error, which was usually too fast (n=257, 85.1%). The most common drugs involved were cefuroxime (n=33), Augmentin® (n=24), Unasyn® (n=23) and cefoperazone (n=19).

Factors Associated with Medication Errors
The bivariate analyses of factors significantly associated with medication errors during the IV drug pre-preparation (Table I) and administration (Table II) were shown. 10 or more IV drugs to be prepared and administered in a ward at a point of time were considered many, whereas 3 or less staff nurses who were attached to a particular ward were considered lack of staff.

Pre-preparation
Administration time at 8.00am significantly predicted an error during IV drug pre-preparation, $\chi^2(2, N=311) = 11.23$, p=0.004. The observation of 10 or less IV drugs has unexpectedly shown to be significantlyχ associated with higher rates of medication errors, $^2(1, N=311) = 14.94$, p=<0.001. Unexpected observation was also seen whereby lack of staff did not cause a greater rateχ of medication errors, $^2(1, N=311) = 6.35$, p=0.012. Meanwhile, there was no significant relationship found between administration technique (bolus or infusion) and medication error in pre-preparation, $\chi^2(1, N=311) = 2.72$, p=0.099.

Table I: Factors Significantly Associated with Medication Errors in Pre-preparation

Factors		Pre-preparation Error, n (%)		p value
		Yes (N=311)	No (N=38)	
Administration	8.00am	220 (70.7)	20 (52.6)	
	12.00pm	73 (23.5)	18 (47.4)	0.004†
Time	4.00pm	18 (5.8)	0 (0.0)	
Many IV drugs	≥10	143 (46.0)	5 (13.2)	< 0.001†
	< 10	168 (54.0)	33 (86.8)	
Number of staff	> 3	59 (19.0)	1 (2.6)	0.012†
Staff nurses	≤3	252 (81.0)	37 (97.4)	

† By Pearson Chi-Square; IV = intravenous

Table II: Factors Significantly Associated with Medication Errors in Administration

Factors		Administration Error, n (%)		p value
		Yes (N=302)	No (N=47)	
Administration	8.00am	219 (72.5)	21 (44.7)	
	12.00pm	65 (21.5)	26 (55.3)	< 0.001†
Time	4.00pm	18 (6.0)	0 (0.0)	
Many IV drugs	≥10	142 (47.0)	6 (12.8)	< 0.001†
	< 10	160 (53.0)	41 (87.2)	
Administration	Bolus	252 (83.4)	15 (31.9)	< 0.001†
Technique	Infusion	50 (16.6)	32 (68.1)	

† By Pearson Chi -Square IV = intravenous

Preparation and Labelling

Variables such as the administration time, amount of IV drugs to be given, lack of staff and administration technique were found not to be significantly associated with medication errors in preparation and labelling of the drugs.

Administration

Administration time at 8.00am was significantly associated with a higher rate of medication error during IV drug administration, $\chi^2(2, N=302) = 25.20$, p=<0.001. The observation of 10 or less IV drugs has also unexpectedly shown to be significantly predicted a higher rate of medicationχ errors, $^2(1, N=302) = 19.54$, p=<0.001. Drugs which were given via bolus were found to have a significantχ association with the administration error rates, $^2(1, N=302) = 60.08$, p=<0.001. There were 3 drugs given as bolus dose, in which theoretically, it is not recommended or preferred. These drugs include azithromycin, acyclovir and erythromycin.

DISCUSSION

Pre-Preparation

IV therapy procedures reveal that aseptic requirements included hand washing before the procedure and cleaning ampoules, vials and IV infusion closures. It was found that there were neither general, written procedures nor guidelines on IV drug preparation and administration in each ward, except for dopamine and adrenaline for emergency cases. The skills and techniques that were taught during diploma and degree educations were applied instead. New staff nurses will therefore learn and acquire the skills from the seniors.

It should not be assumed that the risk of infection is small because of the IV drugs are generally being prepared for immediate use. Recent research in a German hospital following the deaths of 2 patients from meningitis caused by contamination of contrast media found other contaminated multiple dose vials in ward areas, and poor handling and storage of these types of medicine [19].

Preparation

Doses required should be calculated prior to preparation to avoid any deviation of the drug dose or infusion volume.

The use of wrong diluents may cause a reduction in the drug solubility leading to powder particulates being administered to the patient. This can also lead to a reduction in the drug stability and activity and possible drug precipitation.

Not all diluents that are commonly used in the hospitals such as WFI or NaCl solutions are suitable for all IV drugs. The prescription for IV drugs seldom provides information concerning the diluent to be used. Healthcare staff preparing IV drugs in clinical areas should consult the product literature or the pharmacy information services to obtain this information.

Ranitidine and promethazine should be taken aware of that they must be diluted prior to administration. This is strongly supported by the manufacturers as well as the product literature from other sources as listed under Material and Methods. Drugs to be administered within a specific time after reconstitution or dilution should be noted as drugs were found to be less potent or effective when the suggested administration time deviates. Solutions should be thoroughly mixed and checked for absence of particulate matter before use [16].

Providing clinical staff with more readily available information concerning diluents may help to reduce the use of the wrong diluents. The clinical importance and use of this information can be reinforced as part of IV therapy training. Quick reference tables could also be produced for each ward and displayed for easy access. Drugs that are provided together with own diluents (such as omeprazole) or ready-diluted drugs (such as frusemide) are the strategies used to avoid errors in selecting the diluents, thus the medication errors.

Labelling
A significant percentage of drugs that were not labelled were not used immediately (defined as drugs not administered within 10 minutes after preparation) and were stored temporarily in the ward before administration, p=<0.001, FET. This was similarly found in a study [19] and this is an important risk that may cause the wrong drug or dose to be administered.

No recognition was given to the practice of IV drug preparation and temporary storage prior administration. Therefore, the hospital IV therapy procedures and training programmes need to be strengthened by including the requirement to label drugs that are left unattended, even for short periods.

Administration
Full concentration should be given during the IV drug administration to prevent any avoidable lost in drug dose. All IV lines should be checked prior to administration. They should be intact and the drug passage should be clear, no blockage.

The administration rate was usually higher than is recommended, a result that is consistent with a finding [2] with 77.1% incidence of error. Similar findings were also found [19,20], in which they have suggested that the error was often deliberate, that is, individuals were aware that the rate deviated from that prescribed but did not consider it to be clinically significant. They concluded that use of infusion control devices and educational training would prevent rapid administration of bolus doses [21].

It was reported that fast rates of administration are associated with pain, phlebitis and loss of cannula patency [19]. There were a few patients demonstrated painful experience in this study. It was observed that the safe speed of injecting bolus doses was being deliberately violated because of lack of perceived risk, poor role models, and available technology [4].

Errors in administration rate of IV drug infusion were less frequent as majority of the drugs were administered using an infusion rate-controlled device. It was supported by a study [21] that occurrence of wrong administration rate could be significantly reduced by this device. It is good practice to examine IV infusions from time to time while they are running. If cloudiness, crystallization, change of colour, or any other sign of interaction or contamination is observed the infusion should be discontinued [16].

Administration time at 8.00am was found to be significantly associated with a higher rate of IV drug administration error. This could be due to the fact that majority of the drugs, despite their dosing intervals were administered at that point of time. Also, the working shifts of staff nurses are divided into three: 7.00am to 2.00pm, 2.00pm to 9.00pm, and 9.00pm to 7.00am. During the morning shift, the wrong administration time could possibly be explained by this change, whereby the staff nurses need to pass over the duties to another, therefore insufficient time to prepare and administer the drugs on time.

It was similarly revealed in a study [19], whereby it may be argued that staff nurses have insufficient time to administer IV bolus doses safely even when they are reminded of the correct administration rate. This observation is supported by the high percentage of wrong administration time errors in this study. As this may indicate a high work load, wrong administration time errors are likely to be increased if staff nurses have to administer each bolus dose over 3-5 minutes as recommended. If this is the case, it was suggested [19] that alternative methods of IV administration should be used such as short IV infusion therapy that does not require the staff nurses to be at the bedside during drug administration.

Logically, more drugs to be given at a time are usually associated with higher error rates. However, a contrast result was observed. We found no similar results regarding this factor in previous studies. As the reasons for these associations were not entirely clear, this study should be further assessed with larger sample sizes and more advanced statistical models.

Study Limitations
This study has several limitations. In the assessment of the administration rate for IV infusion, the rates were obtained from the staff nurses verbally as these particular drugs were not monitored using an infusion rate-controlled device. Moreover, convenient sampling of wards was done. There were few wards not observed either because there were no IV drugs to be administered at that point of time, or the drugs have been administered before the observation, or the administration time differed from the time for data collection by the observer.

The observer intervened in most of the errors identified that an erroneous medication likely to cause harm to the patient was going to be administered. These incidents were still included as errors. Intervention could have an educational effect and prevent subsequent errors from occurring. However, intervention could introduce a judgmental dimension to the observation, resulting in distress to staff nurses and patients. The effects of such interventions on the error rate are unknown. A major disadvantage of observational research is that it is tiring, which could reduce observer reliability; observer may also process what she sees or hears differently.

The observer only focused on process errors. Our method did not attempt to link the observed process errors to potential clinical outcomes. The inability to detect some factors thought to contribute towards errors (such as level of nursing experience) that might cause the differing practices could have been due to our methodology. Despite this, the prospective design would be the most appropriate to evaluate the medication errors in IV drug preparation and administration in HospSel given the short duration of study.

CONCLUSION

A high rate of IV medication errors at different stages of observation was found in this study. Although majority of the errors do not cause significant harmful clinical outcomes to the patient, training and knowledge needs as well as design

issues should be addressed to reduce these error rates. By looking at the errors encountered, the contributing factors were identified.

As the outcomes from this study, the guidelines on reconstitution and administration of IV drugs were prepared and have been distributed to the wards to help minimize any doubts or confusion related to the IV drug preparation and administration. The study findings were shared among the staff nurses during the continuous medical education sessions conducted. It is recommended that the checklists should be introduced in wards to encourage staff nurses to monitor administration rates regularly, especially IV infusions.

As the hospital pharmacy supplies medications according to the patients, the medications should be placed in the wards similarly to avoid wrong drug administration and to ensure drug availability for the particular patient. This was stressed because the staff nurses in majority of the wards will usually group the patients' medications such as metronidazole as it came in large packages, which do not allow them to be placed in the individual trolley's bin. This occurrence could possibly be explained by the lack of understanding regarding the pharmacy supply system among the staff nurses and therefore, there is a need for them to adhere to this system. It was suggested that every ward should have a cabinet with uniformly divided shelves, representing each bed, which offers a sufficient area to place the medications, respectively.

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