The Effect of Information Provision on Reduction of Errors in Intravenous Drug Preparation and Administration by Nurses in ICU and Surgical Wards

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Abstract- Malpractice in preparation and administration of intravenous (IV) medications has been reported frequently. Inadequate knowledge of nurses has been reported as a cause of such errors. We aimed to evaluate the role of nurses' education via installation of wall posters and giving informative pamphlets in reducing the errors in preparation and administration of intravenous drugs in 2 wards (ICU and surgery) of a teaching hospital in Tehran, Iran. A trained observer stationed in 2 wards in different work shifts. He recorded the nurses' practice regarding the preparation and administration of IV drugs and scored them before and after the education process. 400 observations were evaluated. Of them, 200 were related to before education and 200 were related to after education. On a 0–10 quality scale, mean ±SD scores of before and after education were determined. Mean ±SD scores of before and after education at the 2 wards were 4.51 (±1.24) and 6.15 (±1.23) respectively. There was a significant difference between the scores before and after intervention in ICU (P<0.001), surgery (P<0.001), and total two wards (P<0.001). Nurses' education by using wall poster and informative pamphlets regarding the correct preparation and administration of IV drugs can reduce the number of errors.

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Introduction

Errors may occur in any stage of pharmacotherapy, including the prescribing, transcribing, dispensing, preparation, and administration stages (1). It is reported that medication administration errors are responsible for one-third of medication errors leading to patients' harm (2). Previous studies showed some errors in the preparation and administration of intravenous (IV) drugs in hospitals (3). Calabrese *et al.*, evaluated the type and incidence of medication administration errors in five intensive care units (ICUs) in the USA by observational method. Of 5,744 observations, 187 (3.3%) medication administration errors were detected. The most common type of errors was incorrect infusion rate with 40.1% of total errors (4). Anselmi *et al.*, evaluated the frequency of errors in the preparation and administration of IV drugs in three Brazilian hospitals. They have done the study by direct observation of nursing staff in the process of IV drug preparation and administration. They reported that the most frequent types of errors were wrong doses and omission doses (5).

In Iranian hospitals, unlike the developed countries, there is not any unit for IV admixture for drug preparation. Pharmacy unit of the hospitals only deliver drugs to the hospital wards. So nurses are the healthcare professionals responsible for preparation and administration of IV drugs in Iranian hospitals. Few studies reported medication errors during the process of drug therapy in Iranian hospital inpatients (6,7)

This study was designed to evaluate the effect of nurses' education by a clinical pharmacist in reduction of

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errors in preparation and administration of IV drugs. Educational method used in this study was the installation of wall poster in the nursing stations and giving informative drug pamphlets to the nurses in order to reduce errors during the practice of IV drug preparation and administration.

Materials and Methods

The study was done in the ICU and surgery wards of a teaching hospital affiliated to Shahid Beheshti University of Medical Sciences (Tehran, Iran). These wards were selected because they were the most wards demanded IV drugs from the pharmacy in this hospital. The protocol of the study was approved by the ethics committee of Shahid Beheshti University of Medical Sciences.

The selected ICU and surgery wards had 12 and 25 beds respectively. Medication orders were written by physicians in both wards. In order to delivery drugs to wards, Iranian hospitals typically use ward stock distribution system (WSDS). As in the Iranian hospitals there is not any IV admixture units, injectable drugs are delivered to hospital wards using WSDS and nurses prepare and administer them to patients. In the setting of the study, there were four working shifts in each ward and nurses changed during each shift.

This study consisted of four distinct phases:

Phase 1: Designing the questionnaires

Phase 2: Pre-intervention; observation of IV drug preparation and administration by nurses before education

Phase 3: Interventional phase; education of nurses regarding the correct process of IV drug preparation and administration and

Phase 4: Post-interventional phase; observation of IV drug preparation and administration after nurses' education.

Phase 1: Designing of questionnaires

There are different types of IV drug dosage forms that are affected during the preparation and administration process. Five distinct classes of IV drugs were defined in the study:

1: Lyophilized powder for infusion, 2: Lyophilized powder for bolus injection, 3: Liquid form for infusion, 4: Liquid form for bolus injection 5: Piggy bag infusion.

Five distinct scoring sheets were prepared for each class. Items of each scoring sheets were prepared by reviewing the similar studies (4,8). There were some common and some different items in each sheet depending on the type of the IV drug. For example, in the scoring sheets of the "lyophilized powder for infusion", there was an item about the using of the right diluents, however, there was not such an item in the scoring sheets of "liquid form for infusion". Scoring sheets consisted of 9 to 13 items. Table 1 shows a summary of the characteristics of the scoring sheets.

Phase 2: Pre interventional phase: Observation of drug preparation and administration before nurses education

An observer was stationed in the ICU and surgery wards at the timing of IV drug preparation and administration. The observer was a trained student of pharmacy. He attended in four different work shifts of drug preparation and administration; morning (6 *am*), early afternoon (2 *pm*), late afternoon (6 *pm*), and night (10 *pm*). Nurses were switched in each work shift. The observer followed up the nurses activities during drug preparation and administration and recorded all related aspects of the process. To prevent the effect of attending an observer during the working process of nurses, they were told that he would only like to watch the preparation and administration of IV drugs as a pharmacy student. The observer evaluated 200 opportunity of IV drug preparation and administration. A questionnaire was filled for each opportunity depending on the type of IV drug, and a score was determined for each opportunity.

Phase 3: Interventional phase: Education of nurses

Preparation of wall posters and handing out educational pamphlets to the nurses were used as an educational method in this study. The content of these educational materials were prepared on the basis of two well known references of IV drug medications (9,10). Two posters were designed, and each was installed on the nursing station of the ICU and surgery ward by a clinical pharmacist working in the hospital.

Table 1. Characteristics of five questionnaires used in the study.

No	Intravenous drug type	Example drug	Minimum score	Maximum score
1	Lyophilized powder for infusion	Vancomycin	0	13
2	Lyophilized powder for bolus injection	Hydrocortisone	0	12
3	Liquid form for infusion	Aminophylline	0	11
4	Liquid form for bolus injection	Frusemide	0	10
5	Piggy bag infusion	Metronidazole	0	9

The clinical pharmacist asked the nurses to read the posters and refer to it when they prepare and administer IV drugs. The posters were designed in the format of a table. In each row, there was information about appropriate preparation and administration of each common used drug in the two wards.

The pamphlets were designed to educate the nurses regarding the importance of checking the expiry dates of the medications, hands disinfection before drug preparation, and inspection the solutions for clarity etc. The pamphlets were given to all nurses who were responsible for drug preparation and administration by the same clinical pharmacist too.

Phase 4: Post interventional phase: Re-observation of drug preparation and administration after nurses education

The same observer who evaluated the preparation and administration of IV drugs in phase 2 was stationed in the ICU and surgery wards again at four different timing of drug delivery. He followed up nurses similar to phase 2 and observed another 200 opportunities of IV preparation and administration to patients. Again a questionnaire was filled for each opportunity depending on the type of intravenous drug and a score was calculated for each opportunity. In phases 2 and 4, the observer would intervene if he noticed any malpractice that could be harmful for patients' safety; however the instances were recorded.

Data analysis

Each drug preparation and administration opportunity had a score from 0 to 13. In order to equalize the score of all opportunities, all 400 observations were adjusted to a score between 0-10 by using the below formula:

Adjusted Score = score ×10/maximum score of the same IV preparation administration

It means that if all items related to an IV drug preparation and administration opportunity were correct, the score of that opportunity was 10. For example if all items related to preparing a lyophilized powder for infusion were correct: 13×10/13=10.

We used SPSS software version 10 for analyzing the data. To compare the mean scores of observations before and after nurse's education, paired *t* test or repeated measure test were used considering the normal distribution of data. *P* value<0.01 was considered significant.

Results

This study was done during August 2009 to April 2010. During the study period, 400 observations of IV drug preparation and administration in 46 hospital inpatients admitted to ICU and surgery wards were evaluated. Of the 400 observations, 240 (60%) and 160 (40%) were done in ICU and surgery ward respectively. 200 observations were done before, and 200 were done after education. 36 different types of IV drugs preparation and administration were observed during the study period.

Figure 1 and 2 show the name and frequency of observed drugs in phase 2 (before nurse's education) and phase 4 (after nurse's education) respectively. Mean ± SD score of drug preparation and administration was determined in both phases.

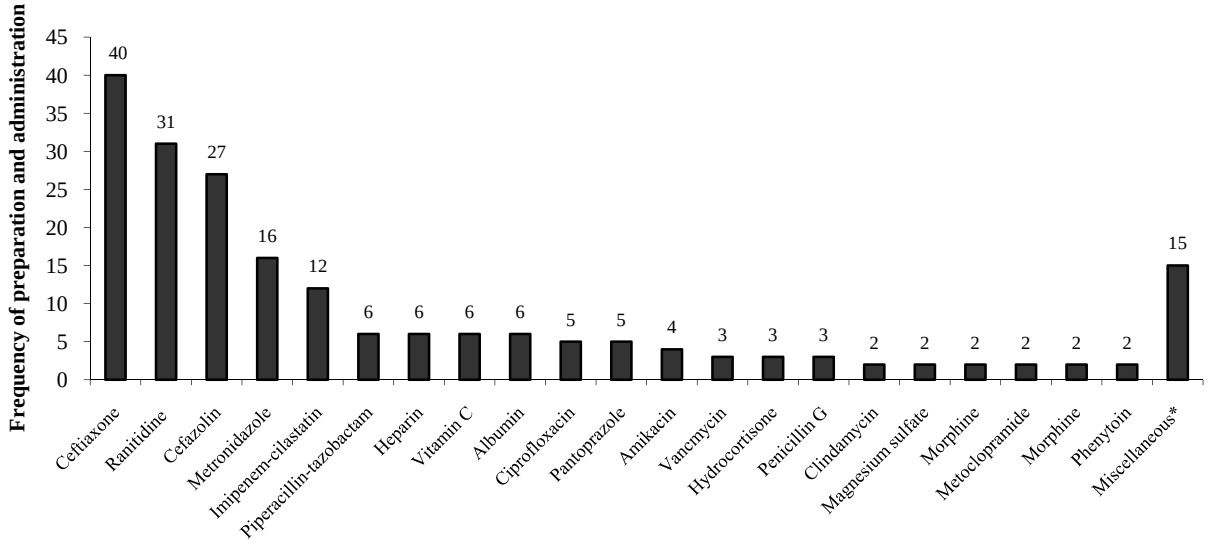

Figure 1. Frequency of intravenous drug preparation and administration in phase 2 of the study

* Miscellaneous refers to 15 drugs, which were prepared and administered only once

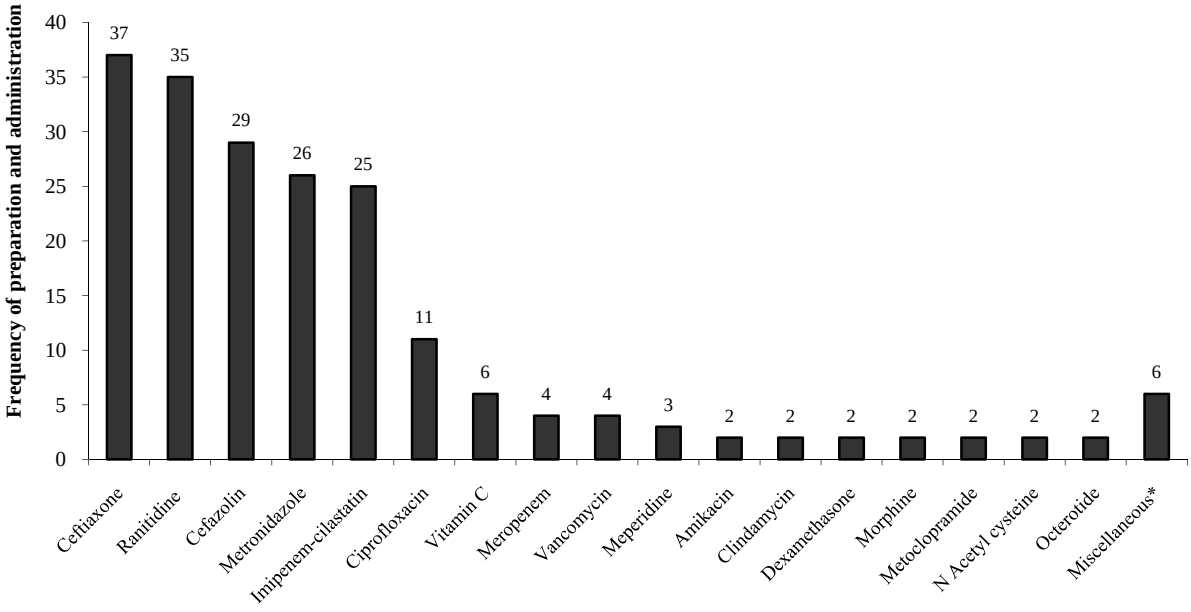

Figure 2. Frequency of intravenous drug preparation and administration in phase 4 of the study

* Miscellaneous refers to 6 drugs, which were prepared and administered only once

Table 2 shows mean ±SD observation scores before and after nurse's education in different work shift in both wards. These drugs were prepared and administered to patients at four different daily times; 6 *am*, 2 *pm*, 6 *pm*, and 10 *pm*. Most drugs were administered to patients in 2 *pm* and 6 *pm*. So the most observations were done in these 2 times. Distribution of observed drug preparation and administration before and after nurse's education were shown in table 2.

Table 2. Mean ± SD scores of drug preparation and administration before and after nurse's education in ICU, surgery and total two wards in different work shifts

Ward	Work Shift	Frequency of observation in phase 2	Mean score in phase 2 (before education)	Frequency of observation in phase 4	Mean score in Phase 4 (after education)
ICU	6 AM	16	4.58±1.23	11	7.04±0.80
	2 PM	34	4.62±1.08	31	5.94±1.07
	6 PM	59	5.10±1.20	62	5.65±1.30
	10 PM	20	4.27±1.28	16	5.99±1.42
	Total	120	4.76±1.21	120	5.90±1.27
Surgery	6 AM	12	4.25±1.42	14	6.46±0.72
	2 PM	20	4.15±1.19	26	6.52±1.06
	6 PM	36	4.02±1.19	30	6.80±0.75
	10 PM	12	4.64±0.86	10	6.39±0.52
	Total	80	4.15±1.19	80	6.52±1.06
Total 2 wards	6 AM	28	4.43±1.30	25	6.72±0.79
	2 PM	54	4.62±1.08	57	6.09±1.30
	6 PM	86	4.53±1.30	92	6.03±1.27
	10 PM	32	4.41±1.14	26	6.14±1.16
	Total	200	4.51±1.24	200	6.15±1.23

Table 3. Mean ±SD scores of observation regarding the most 5 observed drugs before and after nurse's education.

Drug	Total frequency of preparation & administration (in 2 phases)	Mean ±SD score in Phase 2 (before education)	Mean ±SD score in Phase 4 (after education)
Ceftriaxone	77	4.65 ± 1.01	6.41 ± 0.12
Ranitidine	66	3.78 ± 1.71	5.66 ± 1.41
Cefazolin	56	4.95 ± 0.55	6.86 ± 0.80
Metronidazole	42	3.54 ± 0.92	5.59 ± 1.27
Imipenem-cilastatin	37	4.80 ± 0.57	6.30 ± 1.10

Analysis by t test showed that there was a significant difference in the score of each work shift of drug preparation and administration between the two phases; 6 AM (P<0.001), 2 PM (*P*<0.001), 6 PM (*P*<0.001), 10 PM (*P*<0.001). Also by using t test, it was determined that there was a significant difference in mean scores between the two phases in ICU (*P*<0.001), surgery (*P*<0.001), and total two wards (*P*<0.001).

The five most observed drugs in the study were ceftriaxone, ranitidine, cefazolin, metronidazole and imipenem-cilastatin. Table 3 shows mean ±SD observation score of these drugs before and after nurse's education. By using t test it was determined that there was a significant difference between mean score of these drugs in the two different phases regarding preparation and administration; Ceftriaxone (*P*=0.0001), ranitidine (*P*<0.001), cefazolin (*P*<0.001), metronidazole (*P*<0.001), and imipenem-cilastatin (*P*<0.001).

Discussion

IV administration is an important rout of drug delivery to hospital inpatients. IV rout provides rapid action compared with other drug delivery methods. As in this rout drug delivery is not affected by gastrointestinal absorption, optimum blood level may be achieved accurately and immediately; an effect which is not possible by other routs (11). Many observational studies have shown errors in preparation and administration of IV medications (3, 5). Of course, observational methods for evaluating such errors might influence the results. Even when all precautions are taken to decrease the effects of observation; it is possible that the presence of an observer affect nurses' behavior (12). Nevertheless observational method is a common way for assessment of health care professionals in various areas.

Global error rates in preparation and administration of IV drugs have been reported 7% and 36% respectively by Taxis *et al.,* (13). It seems that several factors contribute in occurrence of these types of errors. Increased work load as measured by a low nurse to patient ratio is a risk factor for adverse events (14). A study shows that nurses consider heavy work as a contributing factor in 37% of medication errors (15). Another factor that may be responsible in occurrence of errors is the knowledge deficiency of nurses regarding IV preparation and administration. Ndosi and Newell evaluated nurses knowledge who were working in surgical wards of a hospital in England regarding the commonly administered drugs. They evaluated nurses' knowledge by using a structured interview and questionnaire methods. Finally, they reported inadequate knowledge of pharmacology among studied nurses (16).

It is obvious that IV drug administrators need to take the initiative of developing systems to guarantee the safe medication preparation and administration. In countries such as Iran where there is not yet any distinct IV admixture unit in the hospital pharmacies, increasing the knowledge and practice of nurses regarding the correct preparation and administration of IV drugs may have an important role in decreasing the medication errors. Although paying attention to optimization of other factors that are involved in occurrence of medication errors is necessary, in our study, we only aimed to evaluate the nurses' education via wall poster installation and giving informative pamphlets in decreasing the errors of IV drug preparation and administration.

Most of the previous studies, which evaluated the errors in preparation and administration of IV drugs suggested recommendations on how to minimize the errors (2-4). There are limited studies regarding the effect of educational interventions on the quality of preparation and administration of IV drugs by nurses. Schneider *et al.,* evaluated the efficacy of an interactive CD-ROM program on the rate of medication preparation and administration errors made by nurses at three community hospitals. The nurses were randomized to an intervention group that completed an interactive CD-ROM program on safe medication practices or to a control group. Direct observation was used to evaluate the mean error rates for two groups before and after the

intervention. The results showed an important decrease in the error rates of administration practice after intervention in the intervention group (17).

Tromp *et al.* designed a quasi-experimental study to evaluate the short-term effects of implementing a new protocol for preparation and administration of IV drugs in two internal wards of a medical centre in Netherlands. One hospital was assigned for intervention, and the other was assigned to be the control. Nurses were observed before and after the intervention (implementation of the protocol). The researchers gave scores to the nurses during the stages of preparation and administration of IV drugs. Before intervention, average quality scores were 64 (intervention ward) and 67 (control ward) on a 0–100 quality scale. After the intervention, the nurses at the intervention ward scored 72 compared with 69 in nurses at the control ward. The authors suggested that implementing a protocol for preparation and administration of IV drugs could decrease the number of errors (18).

In this study, we did not have a control group and the nurses were compared with themselves before and after intervention as a semi-quasi study. Similar to Tromp *et al.*, study [18], we gave scores to observations in order to change the qualitative data to quantitative ones and comparing them before and after intervention.

It is probable that nurses' practice differ in various diurnal working shifts. Folkard and Tucker reported that both safety and productivity are decreased at night work shifts (19). As it is possible that work shifts affect the accuracy of drug preparation and administration, we compared distinctively the nurses' scores before and after interventions in four times of IV drug preparation and administration. Difference between the mean nurses' scores before and after education was seen in all four work shifts (6 *am*, 2 *am*, 6*pm*, 10 *pm*). Scott *et al.*, have done a study to determine whether an association exists between the occurrence of errors and hours worked by the nurses and to explore whether these work hours have adverse effects on the nurses' vigilance. They suggested to minimize the use of 12-hour shifts and to limit nurses' work hours to no more than 12 consecutive hours during a 24-hour period for reduction of errors (20). In our study, as the nurse's shift was less than 12 hours, it is predictable that work load hours cannot affect the nurses practice and educational program could result in a significant increase in the practice of nurses in all work shifts including the night ones.

Marques *et al.*, observed a total of 1500 errors in three Brazilian hospitals. Most of the errors (277, 18.5%) were related to antibiotics (21). Also in a meta-analysis by Valentin *et al.* antibiotics and sedative-analgesics were the most common category of drugs with administration errors in 113 ICUs of several countries (3). The most observed drugs in our study are from antibiotic class (ceftriaxone, cefazolin, metronidazole, and imipenem- cilastatin). Before intervention nurse's score regarding preparation and administration of mentioned antibiotics were below 5 (from 10). After the intervention preparation, and administration scores rise above 5 for all of them. It was determined that education was successful regarding optimization of nurse's practice regarding the most common drugs of the wards (antibiotics).

It cannot be expected that practice of nurses regarding IV drug preparation and administration remain constant during the time. Because there was a short time between pre and post intervention, it is possible that the short period of nurses' education caused the significant improvement in the quality of preparation and administration after education. It is also possible that the findings would change if the nurses were observed for a longer period. In conclusion, it seems that in countries such as Iran where both preparation and administration of drugs are duties of nurses, permanent supervision of pharmacists can play an important role in improving the quality of preparation and administration of IV medications in the long run. This can be an issue for future research.

Continuous education and competency assessment for nurses may lead to less error in IV drug preparation and administration. Short continuing educational programs regarding IV drug preparation and administration are recommended.

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