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Medication Errors in Ready-to-Administer Injectable Admixtures Compounded by Pharmacy Personnel: A Study of Hospitals in Northern Thailand

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ABSTRACT

OBJECTIVE To determine the number, types, and severity of medication errors in ready-to-administer injectable admixtures compounded by pharmacy personnel in northern Thai hospitals.

METHODS This retrospective descriptive study was conducted in six hospitals in northern Thailand. Data were gathered from hospital incidence reports over the three-year period 2017-2019. The following data were extracted from each report: stage of error, medication involved, care setting, and severity of error. The National Coordinating Council for Medication Error Reporting and Prevention index was used to categorize the severity of the medication errors. Results are presented as number and percentage.

RESULTS The total number of medication error events in the six hospitals was 405, classified as transcribing (n=59, 14.5%), pre-dispensing (n=217, 53.6%) and dispensing errors (n=129, 31.9%). The most frequent type of pre-dispensing errors was inappropriate techniques in medication compounding (n= 54, 13.3%). Almost all the medication errors were of severity level B (errors resulting in no harm to patients) (n=398, 98.3%). The most frequent errors were reported in antineoplastic agents (n=373, 92.1%).

CONCLUSIONS The great majority of medication errors were pre-dispensing errors with a low level of severity. The provision of strategies to prevent medication errors is necessary for patient safety.

KEYWORDS medication errors, ready-to-administer injection, pharmacist

INTRODUCTION

Injectable therapies are complex, potentially dangerous, and are susceptible to errors. Injection medications have been associated with higher rates of medication administration errors compared to orally administered medications (1). Several studies have reported medication errors which occurred during the injectable medication preparation process, e.g., wrong drug (2,3), wrong diluent (2-7),wrong amount of diluent volume (2,3,5,6), expired medication, preparations which became unstable after dilution (2,5), wrong concentration (3,8,9), wrong

labelling (3), omissions of drugs (9), and inappropriate storage (4). In some cases, medical personnel did not follow a standardized drug preparation process, e.g., not washing the device (8), not sterilizing the vial with alcohol (2), not cleaning the drug preparation area before preparing the medication (2), using an inappropriate drug preparation area and not wearing gloves during preparation and administration of the drug (2,5).

Ready-to-administer medications are recommended as standard practice by the Joint Commission International (10). One category of the ready-to-administer medications is ready-to-administer injectable products. The compounding of medications is a fundamental skill of pharmacy practice. All compounding personnel, including pharmacists and pharmacy technicians, are responsible for compounding and dispensing sterile products. Previous studies (11-13) have demonstrated that preparation of injectable medications by pharmacists results in fewer medication errors.

In some areas of Thailand, hospital pharmacists are responsible for compounding sterile injectable products. Most of these are chemotherapy products and parenteral nutrition admixtures. Due to human resources limitations, injection products are frequently prepared by medical personnel other than pharmacists, especially nurses. One study (14) in Thailand showed that the cost of the ready-to-use system over a 10-year period was about 18 million baht lower than the traditional compounding system by a saving of about 2%. Moreover, the study reported that the ready-to-use system also decreased nurses' workload (14). However, the impacts on medication errors were questionable. Little is known about the rate of medication errors in ready-to-administer injection medications prepared by pharmacists. To the best of our knowledge, there have been no studies of ready-to-administer injectable medications prepared by pharmacists conducted in Thailand. More evidence is needed, especially studies with a sample size large enough to identify appropriate approaches to preventing errors. In this study, we investigated the incidence of medication errors in ready-to-administer injectable admixtures prepared by pharmacists in northern Thai hospitals.

METHOD

Study settings, design and data collection

To publicize the project, invitation letters and copies of the research proposal were sent to all 143 hospitals located in northern Thailand including a discussion of the study's purpose, expected benefits, and risks. Hospitals which agreed to participate in the study and sent acceptance letters to the researcher within one month after the invitation were included in the study.

This retrospective descriptive study gathered data from hospital incidence reports over the three-year period 2017-2019. Reports were drawn from the hospital safety reporting systems, a voluntary system used by healthcare professionals to report many types of safety incidents including medication errors. Medication error reports about ready-to-administer injection preparations by pharmacists were included in the study. The following data were extracted from each report: stage of error (i.e., transcribing, pre-dispensing, or dispensing error), medication involved, care setting, and severity of the error.

The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) index was used to categorize the severity of the medication errors (Table 1) (15). Final confirmation of the data was performed by pharmacists at the study hospitals.

Measures

The primary outcome was medication errors which had been reported through the hospital safety reporting system. Errors were categorized into three types: transcribing, pre-dispensing, and dispensing errors. A transcribing error is a mistake in the identification of a specific type of medication which occurred due to a data entry error. A pre-dispensing error is an error that happened in the process of drug refilling or drug preparation. This type of error can be detected at the pharmacy unit before the drug is dispensed to the patient or before delivery to wards. A dispensing error is defined as a deviation from a prescription that occurs

Table 1. The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) index (15)

Level	Description
A	Events that have the capacity to cause error
B	An error occurred, but the medication did not reach the patient
C	An error occurred that reached the patient but did not cause the 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 prolonged hospitalization
G	An error occurred that may have contributed to or resulted in permanent harm to the patient
H	An error occurs that required intervention necessary to sustain the life of the patient
I	An error occurred that have contributed to or resulted in the patient's death

Table 2. Definition of categories of medical errors in the study (16-18)

Types of medication errors	Definitions
Omission of drug	The prescribed medication(s) was/were not prepared or did reach the patient.
Preparation without prescription	The medication(s) was/were prepared without a physician's prescription.
Wrong diluent	The prescribed medication(s) was/were not reconstituted or diluted with the correct type of diluent or solution or did not follow the physician's prescription.
Wrong amount of diluent volume	The prescribed medication(s) was/were not reconstituted or diluted with the correct volume of diluent or solution or did not follow the physician's prescription.
Wrong drug	The prescribed medication(s) was/were not prepared or dispensed correctly according to the physician's prescription.
Wrong concentration	The prescribed medication(s) was/were prepared in a dose or concentration higher than or lower than the amount prescribed by the physician.
Wrong label	The label of prescribed medication(s) was/were incomplete, incorrect or did not follow the physician's prescription.
Wrong quantity	The amount of the prescribed medication(s) dispensed was/were incorrect or did not follow the physician's prescription.
Wrong preparation technique	The preparation of the prescribed medication(s) was done using inappropriate procedures or improper techniques.
Wrong storage	The prescribed medication(s) was/were kept or stored incorrectly.

during the dispensing process, e.g., a dose/item error, incorrect labelling, and identification of the wrong patient. Detailed definitions of each type of medication error are presented in Table 2.

Data analysis

Data were analyzed using statistical software. Types of medication errors and the NCC MERP medication error index were analyzed using descriptive statistics. The results are presented as number and percentage.

Ethical considerations

The study protocol and ethical principles were reviewed and approved by the University of Phayao Human Ethics Committee (Ref. No. 2/193/62). The research protocol was approved by the individual hospitals as necessary. Before the initial data collection, the eligible hospitals signed an informed consent. Anonymity and confidentiality of all participants was assured. As the data was collected, neither the names nor personal details of the patients or of the data reporters were recorded at any stage of the data collection process.

RESULTS

Hospital characteristics

Of the 143 hospitals in the northern region of Thailand, nineteen (13.3%) responded, of which six (4.2%) met the inclusion criteria. Thirteen hospitals were excluded due to an

incomplete hospital safety reporting system and ethical review process. The participating hospitals included five government hospitals and one private hospital. The hospitals were located in Phayao (n=1), Phrae (n=1), Chiang Mai (n=3), and Chiang Rai (n=1) provinces. Five were general hospitals with 30-500 beds and one was a teaching hospital with more than 1,000 beds. The ready-to-administer injection preparations were prepared in a variety of settings in two hospitals, and in chemotherapy and parenteral nutrition departments in four hospitals.

Types of medication errors

The number of medication error reports in ready-to-administer injection preparations by pharmacists in 2017, 2018 and 2019 were, respectively, 185 (45.7%), 118 (29.1%), and 102 (25.1%), a total of 405 events. Those events included 59 transcription errors (14.5%), 217 pre-dispensing errors (53.6%) and 129 dispensing errors (31.9%). The types of medication errors in ready-to-administer injection preparations by pharmacists are presented in Table 3.

The transcribing errors involved incorrect entry of physician's orders into the computer system and included wrong diluents (n=22, 5.4%), wrong drugs or items (n=20, 4.9%), wrong patients (n=13, 3.2%), and wrong volume of diluents (n=4, 1.0%). The majority of pre-dispensing errors occurred in the process of production (n=89, 22.0%); the most frequent pre-dispensing errors were preparing using the wrong preparation techniques (n=54; 13.3%), using the wrong diluent (n=30, 7.4%) and using the wrong dose or strength of

Table 3. Types of medication errors in ready-to-administer injection preparations prepared by pharmacists [n (%)]

Types of medication errors	Overall (n=405)	2017 (n=185)	2018 (n=118)	2019 (n=102)
1. Transcribing errors	59 (14.5)	38 (20.5)	6 (5.1)	15 (14.7)
Wrong diluent	22 (5.4)	15 (8.1)	0 (0.0)	7 (6.9)
Wrong patient	13 (3.2)	6 (3.2)	5 (4.2)	2 (1.9)
Wrong dose	11 (2.7)	9 (4.9)	1 (0.9)	1 (1.0)
Wrong drug	9 (2.2)	8 (4.3)	0 (0.0)	1 (1.0)
Wrong volume of diluent	4 (1.0)	0 (0.0)	0 (0.0)	4 (3.9)
2. Pre-dispensing errors	217 (53.6)	89 (48.1)	76 (64.4)	52 (51.0)
2.1 Pre-preparation errors				
Omission of drug	27 (6.7)	13 (7.0)	7 (5.9)	7 (6.9)
Wrong diluent	18 (4.4)	7 (3.8)	8 (6.8)	3 (2.9)
Wrong drug	8 (2.0)	3 (1.6)	4 (3.4)	1 (1.0)
Preparation without prescription	3 (0.7)	2 (1.1)	0 (0.0)	1 (1.0)
2.2 In-process errors				
Wrong preparation techniques	54 (13.3)	21 (11.4)	23 (19.5)	10 (9.8)
Wrong diluent	30 (7.4)	13 (7.0)	9 (7.6)	8 (7.8)
Wrong volume of diluent	3 (0.7)	1 (0.5)	0 (0.0)	2 (2.0)
Wrong concentration	2 (0.5)	0 (0.0)	0 (0.0)	2 (2.0)
2.3 Post-preparation errors				
Wrong concentration	29 (7.1)	11 (5.9)	14 (11.9)	4 (3.9)
Wrong diluent	15 (3.7)	7 (3.8)	3 (2.5)	5 (4.9)
Wrong drug	15 (3.7)	7 (3.8)	4 (3.4)	4 (3.9)
Wrong label	10 (2.5)	4 (2.2)	2 (1.7)	4 (3.9)
Wrong storage	3 (0.7)	0 (0.0)	2 (1.7)	1 (1.0)
3. Dispensing errors	129 (31.9)	58 (31.4)	36 (30.5)	35 (34.3)
Omission of drug	61 (15.1)	34 (18.4)	13 (11.1)	14 (13.7)
Wrong concentration	18 (4.4)	6 (3.2)	6 (5.1)	6 (5.9)
Wrong quantity	17 (4.2)	7 (3.8)	3 (2.5)	7 (6.9)
Wrong label	14 (3.5)	0 (0.0)	11 (9.3)	3 (2.9)
Wrong storage	10 (2.5)	9 (4.9)	0 (0.0)	1 (1.0)
Wrong drug	7 (1.7)	2 (1.1)	2 (1.7)	3 (2.9)
Wrong diluent	2 (0.5)	0 (0.0)	1 (0.8)	1 (1.0)

Table 4. Severity of medication errors and medications involved (n=405)

Categories	Number of errors (%)			Total
	B	C	D	
Medication errors				
1. Transcribing errors	59 (14.8)	0 (0.0)	0 (0.0)	59 (14.5)
2. Pre-dispensing errors	217 (54.5)	0 (0.0)	0 (0.0)	217 (53.6)
3. Dispensing errors	122 (30.7)	3 (100.0)	4 (100.0)	129 (31.9)
Drug classes				
1. Antineoplastic agents	370 (92.9)	2 (66.7)	1 (25.0)	373 (92.0)
2. Antibiotics	12 (3.0)	0 (0.0)	0 (0.0)	12 (2.9)
3. Antidotes	7 (1.7)	0 (0.0)	0 (0.0)	7 (1.7)
4. NSAIDs	3 (0.7)	0 (0.0)	1(25.0)	4 (0.9)
5. Vasopressors	1 (0.3)	0 (0.0)	1 (25.0)	2 (0.5)
6. Vitamins	2 (0.5)	0 (0.0)	0 (0.0)	2 (0.5)
7. Antipsychotics	0 (0.0)	0 (0.0)	1 (25.0)	1 (0.3)
8. Anticholinergic agents	0 (0.0)	1 (33.3)	0 (0.0)	1 (0.3)
9. Loop diuretics	1 (0.3)	0 (0.0)	0 (0.0)	1 (0.3)
10. Neurotrophic agents	1 (0.3)	0 (0.0)	0 (0.0)	1 (0.3)
11. Electrolyte supplements	1 (0.3)	0 (0.0)	0 (0.0)	1 (0.3)

NSAIDs; non-steroidal anti-inflammatory drugs

intravenous products (n=29, 7.1%). The most frequent dispensing errors were omission of prescribed medications (n=61, 15.1%), wrong dose/strength (n=18, 4.4%) and wrong amount of drug dispensing (n=17; 4.2%), respectively.

Severities of medication errors and medication involved.

The NCC MERP index for categorizing medication errors is shown in Table 4. None of the reported errors resulted in harm to patients. Of the reported errors, in 398 cases the medication did not reach the patients (B level), in 7 cases the medication reached the patient of which 3 did not cause patient harm (C level), and 4 errors resulted in the need for increased patient monitoring but did no harm (D level). Most of the events involved antineoplastic agents (n=373, 92.1%). Most of the reported medication errors involved fluorouracil (n=73), methotrexate (n=31) or cisplatin (n=27) (data not shown). The three in C level errors involved fluorouracil (n=1), gemcitabine (n=1) and hyoscine (n=1). The errors in D level involved cyclophosphamide (n=1), haloperidol (n=1), norepinephrine (n=1), and parecoxib (n=1).

DISCUSSION

Proper utilization and analysis of medication error reports can provide valuable insights into system-based pitfalls regardless of the care setting. In the present study, half of the medication errors were pre-dispensing errors (53.6%). This result is similar to previous studies which have reported 88.6% of pre-dispensing errors in out-patient pharmacy service (19), 50% in in-patient pharmacy services(20), and 51% in community pharmacies (21). Prior studies have demonstrated that systematic rechecking by a pharmacist can help prevent and correct medication errors. In one study, 88.6% of pre-dispensing errors were detected by pharmacists (19). Another study confirmed that pharmacists can have an important role in preventing, detecting and correcting medication errors (21).

The majority of pre-dispensing errors in the current study involved inappropriate techniques in medication compounding (n=54, 13.3%). A disguised observation study of intravenous preparations by nurses in two hospitals in the UK found that errors related to improper technique occurred in 13.3% of intravenous doses (22). A study in two Vietnamese hospitals reported 34.4% of errors were related to improper technique (18). Errors in the preparation phase can have serious consequences as that is the last step before administration. The inappropriate technique errors in our study were reported to have occurred in the pre-dis-

pensing process and the medications did not reach the patient. However, the evidence base for evaluating the accuracy of intravenous admixture units prepared by pharmacy personnel appeared to be weak. The second and third most frequent types of pre-dispensing error were "wrong diluent" (detected during the process of compounding) and "wrong concentration" (detected after the dilution process). Wrong concentration errors in intravenous therapy were reported to account for 148 of 799 errors (18.5%) in the neonatal intensive care unit in one study (16). The most frequent types of errors in intravenous admixtures reported from five hospitals in the US were wrong dose (70.0%) and wrong based solution (16.0%) (wrong volume 6% and wrong content 10%) (23).

This study found 31.9% of the errors were dispensing errors, significantly higher than the 1.1% reported in other medication error studies in Thailand (20) and the 3.88% in studies in Mexico (16). Most dispensing errors in our study involved drug omission (15.1%). Previous studies have reported drug omission error rates of 3% in US (23) and 5% in Vietnam (24). A possible cause of this type of error could be an imbalance between the workload and the number of pharmacy personnel. Four of the six participating hospitals in this study had only two pharmacists on staff preparing the intravenous admixtures. The other two hospitals had 3 and 6 pharmacists on staff.

Our finding of 98.3% NCC MERP medication index level B errors is similar to a previous study which reported 97.3% level B errors (20). Although the errors in this study resulted in no harm to patients, possible causes of the errors should be analyzed. A regular review of risk management procedures should be implemented to reduce the incidence of near miss events and to help protect against medication errors which could cause harm.

This study found that injectable chemotherapy was the most common type of medication error (92.1%) and that the most frequent errors involved fluorouracil, methotrexate, and cisplatin. Previous studies have reported findings similar to the present study, e.g. the highest rate of errors involved methotrexate, fluorouracil, and vincristine (25). The high error rate in this study may be due to the participating hospitals providing significant levels of chemotherapy preparation services.

This is the first study focused on medication errors among ready-to-administer injection preparations done by hospital pharmacists in Thailand. The issue of injection preparation has received only limited systematic investigation by researchers, and is recognized as an area that requires attention. The results of this study may be used as empirical evidence that can help emphasize the need to design and implement improved strategies, for example, increasing the number of pharmacists to match the workload and implementing continuous error-prevention training programs.

This study has some limitations. First, it is likely that not all medication errors which occurred during the study period were recorded or reported under the hospital safety reporting system, and therefore were not included in this study. Second, this study analyzed only voluntary reports from 2017 to 2019. Potential sources of negative impact on the study findings include under-reporting, bias and internal validity problems. Third, this study does not detail of the incidents or the rates of the different types of medication errors. As some participating hospitals did not have a complete record of medication errors, the analysis was incomplete and the results might not reflect the actual annual incidence of medication errors. Despite these limitations, results of this study should be beneficial for the further development of intravenous medication safety processes. Further study focusing on the etiology of medication errors and the economic impact of those errors is needed.

CONCLUSIONS

This study of medication errors presents the number and characteristic of medication errors in ready-to-administer injection preparations by pharmacists in northern Thai hospitals. A large number of the medication errors were pre-dispensing errors with a low level of severity. This study highlights the importance of complete and accurate reporting of medication errors, patient medication safety and the need

for effective guidelines to help prevent medication errors in hospitals.

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AUTHOR CONTRIBUTIONS

PR drafted the first manuscript. OM conducted the analysis, interpreted parts of the data and revised the manuscript. CC contributed to the data collection and conception of the analysis. KK, JD, ST, and MD conducted the data collection at the study sites. KO assisted with the analysis. All authors contributed toward the study design, data analysis, drafting and critical revision of the manuscript. The final draft manuscript was approved by all authors prior to submission for publication.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

REFERENCES

1. Shane R. Current status of administration of medicines. Am J Heal Pharm. 2009;66(5 Suppl3):S42-8.
2. Ong WM, Subasyini S. Medication errors in intravenous drug preparation and administration. Med J Malaysia. 2013;68:52-7.
3. Hermanspann T, van der Linden E, Schoberer M, Fitzner C, Orlikowsky T, Marx G, et al. Evaluation to improve the quality of medication preparation and administration in pediatric and adult intensive care units. Drug Healthc Patient Saf. 2019;11:11-8.
4. Fahimi F, Ariapanah P, Faizi M, Shafaghi B, Namdar R, Ardakani MT. Errors in preparation and administration of intravenous medications in the intensive care unit of a teaching hospital: an observational study. Aust Crit Care. 2008;21:110-6.
5. Abbasinazari M, Talasaz AH, Mousavi Z, Zare-Toranposhti S. Evaluating the frequency of errors in preparation and administration of intravenous medications in orthopedic, general surgery and gastroenterology wards of a teaching hospital in Tehran. Iran J Pharm Res. 2013;12:229-34.
6. Prot S, Fontan JE, Alberti C, Bourdon O, Farnoux C, Macher MA, et al. Drug administration errors and their determinants in pediatric in-patients. Int J Qual Heal Care. 2005;17:381-9.
7. Vijayakumar A, Sharon E, Teena J, Nobil S, Nazeer I. A clinical study on drug-related problems associated with intravenous drug administration. J Basic Clin Pharm. 2014;5:49-53.
8. Vazin A, Delfani S. Medication errors in an internal intensive care unit of a large teaching hospital: a direct observation study. Acta Med Iran. 2012;50:425-32.
9. Wirtz V, Taxis K, Barber ND. An observational study of intravenous medication errors in the United Kingdom and in Germany. Pharm World Sci. Pharm World Sci. 2003;25:104-11.
10. Joint Commission International. Joint Commission International Accreditation Standards for Hospitals. 7th ed. Illinois (US): Joint Commission Resources; 2020. p. 424.
11. Morris AM, Schneider PJ, Pedersen CA, Mirtallo JM. National survet of quality assurance activities for pharmacy-compounded sterile preparations. Am J Health Syst Pharm. 2003;60:2567-76.
12. Webster CS, Merry AF, Gander PH, Mann NK. A prospective, randomised clinical evaluation of a new safety-orientated injectable drug administration system in comparison with conventional methods. Anaesthesia. 2004;59:80-7.
13. American Society of Health System Pharmacists. ASHP Guidelines on compounding sterile preparations. Am J Health Syst Pharm. 2014;71:145-66.
14. Noparatayaporn P, Thaweethamcharoen T, Laocharoenkeat A, Narkchuay P, Klinniyom A, Nopmaneejumruslers C, et al. Economic evaluation of ready-to-use injectable medications by pharmacy department compared with the traditional system of individual preparation by nurse. Siriraj Med J. 2019;71:25-30.
15. Hartwig SC, Denger SD, Schneider PJ. Severity-indexed, incident report-based medication error-reporting program. Am J Hosp Pharm. 1991;48:2611-6.
16. Ramírez-Camacho MA, Lara Aké NJ, Puga Tuyub GA, Torres-Romero JC. Medication errors of intravenous therapy in the neonatal intensive care unit of a second-level hospital in southeastern Mexico. Lat Am J Pharm. 2020;39:604-11.
17. Anacleto TA, Perini E, Rosa MB, César CC. Drug-dispensing errors in the hospital pharmacy. Clinics. 2007;62:243-50.
18. Nguyen HT, Pham HT, Vo DK, Nguyen TD, Van Den Heuvel ER, Haaijer-Ruskamp FM, et al. The effect of a clinical pharmacist led training programme on intravenous medication errors: a controlled before and after study. BMJ Qual Saf. 2014;23:319-24.
19. Soontornpas R, Boonlue T, Kulvarotama S, Soontornpas C. Monitoring of near miss error by pre-dispensing recheck at out-patient pharmacy service, Department of Pharmacy, Srinagarind Hospital. Srinagarind Med J. 2012;27(Suppl):150-1. (In Thai)
20. Kruerut P. The development of preventing medication error for patient safety in Bannasan hospi-

tal. Region 11 Medical Journal. 2018;32:871-80. (In Thai)
21. Lynskey D, Haigh SJ, Patel N, Macadam AB. Medication errors in community pharmacy: an investigation into the types and potential causes. Int J Pharm Pract. 2007;15:105-12.
22. Taxis K, Barber N. Causes of intravenous medication errors: an ethnographic study. Qual Saf Heal Care. 2003;12:343-7.
23. Flynn EA, Pearson RE, Barker KN. Observational study of accuracy in compounding i.v. admixtures at five hospitals. Am J Health-Syst Pharm. 1997;54:904-12.
24. Nguyen HT, Nguyen TD, Van Den Heuvel ER, Haaijer-Ruskamp FM, Taxis K. Medication errors in Vietnamese hospitals: prevalence, potential outcome and associated factors. PLoS One. 2015;10:1-12.
25. Tavakoli-Ardakani M, Omidi S, Eshraghi A, Salamzadeh J. Medication errors in administration of chemotherapeutic agents: an observational study. Iran J Pharm Sci. 2013;9:1-11.