

# A Meta-Analysis of the Effects of Intervention on the Prevention of Medication Administration Errors in Nurses

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## ABSTRACT

**Background/Objectives:** Medication errors are one of the most common medical incidents occurring in hospitals and are the major health events. This study aims to perform a meta-analysis of the effects of intervention on the avoidance errors in nurses and to provide basic data for evidence-based nursing practice.

**Method/Statistical Analysis:** CINAHL, PubMed, EMBASE, Ovid, the Cochrane Library and relevant articles published in January 1975 and in February 2018 were searched. Randomized controlled trial and non-randomized controlled trials were included. Risk of Bias and Risk of Bias Assessment tool for Non-randomized Studies were used to evaluate quality of the selected studies. The random effects model was used considering various characteristics of the selected studies to calculate average effect size.

**Findings:** A total of 3538 studies were retrieved from five electronic databases, thirty studies of which were included in this study: five were randomized controlled trials and eight were non-randomized controlled trials. Interventions were medical devices and education intervention. Medical devices intervention was useful to directly reduce nurse medication administration errors (OR=0.64, 95% CI: 0.45 to 0.93, p=.020), and simulation education was effective in improving nurse medication knowledge (SMD=1.06, 95% CI: 0.07 to 2.05, p=.036).

**Improvements/Applications:** The results of this study can be widely used as the bias for the selection of useful moderations to increase safety of patients at nursing sites.

**Keywords:** Medication administration errors, Systematic review, Meta-analysis, Nurses, Medical devices, Simulation.

## Introduction

A medication error is a type of error that occurs most frequently among medical errors caused by medical personnel<sup>[1]</sup>, and it is one of major adverse events. There are about 400,000 annual injuries related to medication<sup>[2]</sup>, and it was reported that 6.7% of all inpatients are led to injury or death from medication errors<sup>[3]</sup>. In the United States, 1.5 million patients suffered from medication accidents every year, among which 7,000 patients were reported to die<sup>[4]</sup>. The European Union also reported that about 8~12% of patients experience a medical accident

that includes an adverse drug event in hospitals<sup>[5]</sup>, and the National Health Service of the United Kingdom spends 100~250 million pounds on medical accidents including medication errors<sup>[6]</sup>. In addition, it was reported that about 7% of inpatients experienced at least one adverse medical accident during their hospitalization period<sup>[7]</sup>.

Medication is an important part of nursing service and one of the most dangerous parts of nursing practice. Therefore, medication is the most frequently performed task of nurses, which consumes about 40% of overall nursing activity time<sup>[8]</sup>. Safe administration of medicines needs to be preceded by proper prescription of doctors and accurate preparation of pharmacists, but nurses play the final role of administering medicines to patients. They are required to have accurate knowledge, administer medicines according to 5-RIGHT, monitor the effects and side effects, and educate patients about medicines. Kräheühl-Melcher<sup>[9]</sup> reported that 53% of medication

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errors occur during administration by nurses, more often compared to prescription and preparation of medicines. When a medication error occurs, patients experience body injury, life threat, extension of hospitalization period and tremendous increase of medical expenses due to a waste of resources [10]. Nurses lose job satisfaction, which results in lowered work productivity [11]. As a result, reduced work productivity of nurses has an adverse effect on quality of nursing service received by patients [12].

The causes of medication errors were largely divided into personal disposition and organizational environment. Such personal disposition and organizational factors were found to affect medication of nurses [13]. Also, it was reported that 76% of medication errors were preventable and 56% of them were caused by human errors [14]. Based on these studies that correlated human medication errors with human factors, it would be necessary to examine personal factors, organizational factors and environmental factors associated with nurses who perform medication and develop an intervention method that can identify interactions among different factors to prevent medication errors.

Much time and effort are needed to develop a medication error intervention method appropriate for nursing sites. However, to make improvement on medication errors that are constantly occurring, it is necessary to combine the effects found in previous studies and compare size of the effects of different interventions, examining information about an efficient intervention based on size of the effects according to variables. Accordingly, this study aims to determine study environment, variables, intervention effects and size of effects for the study of intervention methods to prevent medication errors through meta-analysis by presenting comprehensive, reliable and consistent results. Such empirical data will present the grounds for future studies on medication error prevention programs and interventions.

## Method

**Inclusion Criteria and Study Selection:** This study selected data according to the PICO-SD (Participants, Intervention, Comparison, Outcomes, Study Design), a systematic literature reporting guideline proposed by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) Group. Participants are

nurses in hospital where they administer medication to the patients. Interventions are implemented in order to prevent the nurse's medication errors. The comparison group is not intervened for the prevention of medication errors. Outcomes are the research that shows the error rate and knowledge score of medication administration. The study design was limited to randomized controlled trial or non-randomized controlled clinical trial.

**Data Search:** In this study, we conducted an online search using an academic search database and a handwriting search through reference documents for the papers published until February 2018. Five databases were reviewed: CINAHL, PubMed, EMBASE, Ovid, the Cochrane Library. Major keywords were derived from subject that constitute the core question as medication/drug; organization/administration, pharmaceutical preparations, error/incident/near miss/adverse event/sentinel event; nurses.

**Data Extraction:** The data selection process was independently performed by two reviewers (HL and research assistant). The studies excluded from the outcomes as follow: non-experimental studies such as survey and qualitative research, studies that cannot figure out the effect of preventative intervention, studies performed in the outpatient setting, abstract and case study without its original text.

**Assessing the Quality of the Selected Studies:** Among the final selected studies, randomized controlled trials were evaluated using the RoB (The Cochrane's Risk of Bias) tool developed by Cochrane Bias Method Group, the non-randomized controlled trials were evaluated using the RoBANS (Risk of Bias Assessment tool for Non-randomized Studies) tool developed by National Evidence-based Healthcare Collaboration Agency. The risk of bias for each study, and for each criterion, was classified as being low, high or unclear.

## Data Analysis

The general characteristics of the selected studies, such as research information, research methods, subjects, interventions, and research results, were analyzed and coded. Effect sizes and homogeneity tests of the study were calculated by the use of Comprehensive Meta-Analysis 3.0 Version. Random effect model was used in consideration of heterogeneity between studies, odd ratio and standardized mean difference were used to calculate the effect size [15].

## Results and Discussion

### Result

**Data Selection:** A total of 3538 studies were searched and 2368 of them were eliminated by duplication. 87 studies of the remaining 1170 were selected in compliance with the selection criteria by reviewing the title and abstract. 75 studies were excluded from the 85 studies because of the exclusion criteria. Thus, the final 13 studies were applied to the meta-analysis [Figure 1].

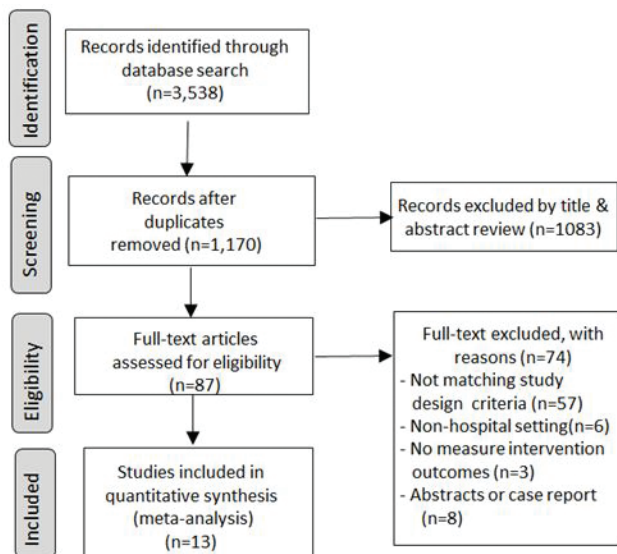


Figure 1: Flowchart of study selection

**Characteristics of Studies:** Five of reviewed 13 studies were classified as RCT studies and another eight as NRCT studies. The major features of the thirteen studies are summarized in Table 1. Looking at the yearly distribution of the studies, two intervention studies were conducted until 2000, seven from 2001 to 2010, and four after 2010[Table 1].

**Assessing Risk of Bias in Included Studies:** Characteristics of the bias risk assessment used in this

study are as presented in Figures<sup>[2,3]</sup> for RCT and NRCT. Based on the risk of bias assessment on RCTs, 65% of studies showed low risk of bias in the domain of random sequence generation and allocation concealment. About 35% of studies were described as random sequence generation but were unclear because they did not describe the specific method. Sham intervention was carried out in 65% of studies for blinding of participants and personnel, and about 65% of studies showed low risk of bias in blinding of outcome assessment. All studies showed low bias in the domain of incomplete outcome data and selective reporting. Other biases were determined by intervention manual and expertise of intervention providers, and 59% of studies showed low risk of bias [Figure 2].

All studies showed low risk of bias NRCT selective of participants. Whereas about 57% of studies were confirmed with confounding variables, other 43% of studies were evaluated to be unclear. Although all studies used a standardized tool for measurement of intervention, only 29% of studies performed repeated measurement and risk of bias was high. Most studies were found to have low bias for detection bias, attrition bias and reporting bias [Figure 3].

**Type of Intervention Implemented:** Among the various interventions applied to prevent medication administration errors were divided into two types: medical device interventions and educational interventions. Medical device interventions are automated medications dispensing system <sup>[16,17]</sup>, computerized prescribing <sup>[18]</sup>, bar-code-assisted medication administration <sup>[19]</sup>, Educational interventions are dedicated medication nurses <sup>[20]</sup> or pharmacist-led training <sup>[21]</sup>, traditional instructor-led education <sup>[22]</sup>, education using electronic devices <sup>[23-26]</sup>, and simulation-based learning <sup>[27,28]</sup>.

Table 1: General characteristics of included studies

No.	Author (year)	Country	Design	Setting		Intervention description	Main outcome measures
				Intervention group	Control group		
1.	Barker et al. (1984)	USA	NRCT	General surgery unit	General surgery unit	Automated bedside dispensing machine	Medication error rate
2.	Cavell and Hughes (1997)	UK	NRCT	General medical unit	General medical unit	Computerized prescribing system	Medication error rate
3.	Chapuis et al. (2010)	France	RCT	MICU	MICU	Automated bedside dispensing machine	Medication error rate

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4.	Deyoung et al. (2009)	USA	NRCT	MICU	MICU	Bar-code-assisted medication administration	Medication error rate
5.	Ford et al. (2010)	USA	NRCT	CCU	MICU	Simulation-based learning educational sessions	Medication error rate Medication knowledge
6.	Greengold et al. (2003)	USA	RCT	Medical unit, Surgical unit	Medical unit, Surgical unit	Dedicated nurses with medication safety education	Medication error rate
7.	Kim (2014)	Korea	NRCT	6 mixed ICU	4 mixed ICU	Smartphone application for medication confirmation	Medication knowledge, Medication safety activities, Certainty of knowledge
8.	Lu et al. (2013)	Taiwan	RCT	11 mixed ward	10 mixed ward	60-min Educational PowerPoint lecture	Medication knowledge
9.	Nguyen et al. (2014)	Vietnam	NRCT	ICU	PSU	Pharmacist-led training of nurses	Medication error rate
10.	Schneider et al. (2006)	USA	RCT	Medical unit Medical-surgical unit	Medical unit Medical-surgical unit	Interactive CD-ROM program on safe medication practice	Medication error rate
11.	Simonsen et al. (2014)	Norway	RCT	-	-	Interactive internet-based e-learning course	Medication knowledge, Certainty, Risk of error
12.	Sung et al. (2008)	Korea	NRCT	Medical unit Surgical unit	Medical unit Surgical unit	Blended learning program with e-learning	Medication knowledge, Self-efficacy, Medication administration ability
13.	Tsai et al. (2008)	Taiwan	NRCT	Large medical center	Large medical center	Virtual reality computer simulation	Medication knowledge

**NRCT:** non-randomized controlled trial, **RCT:** randomized controlled trial, **MICU:** medical intensive care unit, **CCU:** coronary critical care unit. **PSU:** post-surgery unit

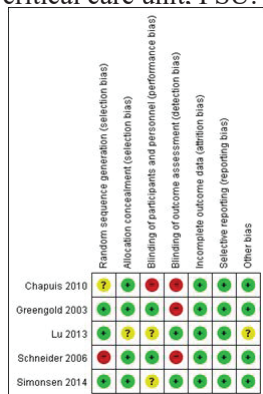


Figure 2: RoB summary

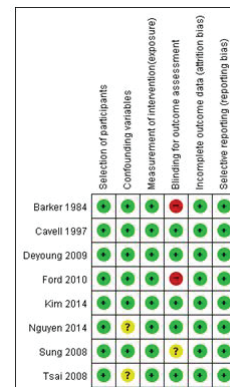


Figure 3: RoBANS summary

**Effects of Interventions:** As 13 studies that presented the effects of medication error interventions were found to be heterogeneous ( $p < .001$ ;  $I^2:95\%$ ), subgroup analysis was performed to explore heterogeneity. Heterogeneity exploration was classified into outcome variables, namely the medication administration error rate and medication knowledge.

Effect size (odds ratio) of the medication error intervention carried out to reduce the medication administration error rate was 0.66 (95% CI: 0.47 to 0.93), but heterogeneity was high ( $p < .001$ ,  $I^2:95\%$ ). To verify heterogeneity, effect size was confirmed separately for different intervention types including the medical device intervention and education intervention.

Whereas the medical device intervention was effective (OR=0.64, 95% CI:0.45 to 0.93,  $p=.020$ ), the education intervention was ineffective (OR=0.79, 95% CI: 0.31 to 2.02,  $p=.618$ ) [Figure 4].

Effect size (standardized mean difference) of the medication error intervention carried out to improve medication knowledge was 1.57 (95% CI: 1.29 to 1.85), but heterogeneity was high ( $p < .001$ ,  $I^2:95\%$ ). To verify heterogeneity, effect size was confirmed separately for different characteristics of the education intervention including e-learning, lecture and simulation. Simulation was effective (SMD=1.06, 95% CI: 0.07 to 2.05,  $p=.036$ ) and e-learning was ineffective (SMD=0.33, 95% CI: -0.82 to 1.49,  $p=.573$ ) [Figure 5].

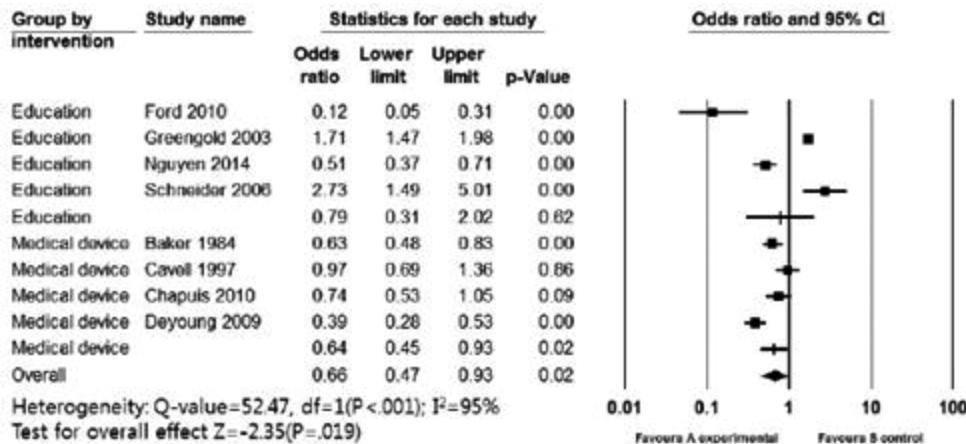


Figure 4: Effect of medication administration rate on intervention type of forest plot

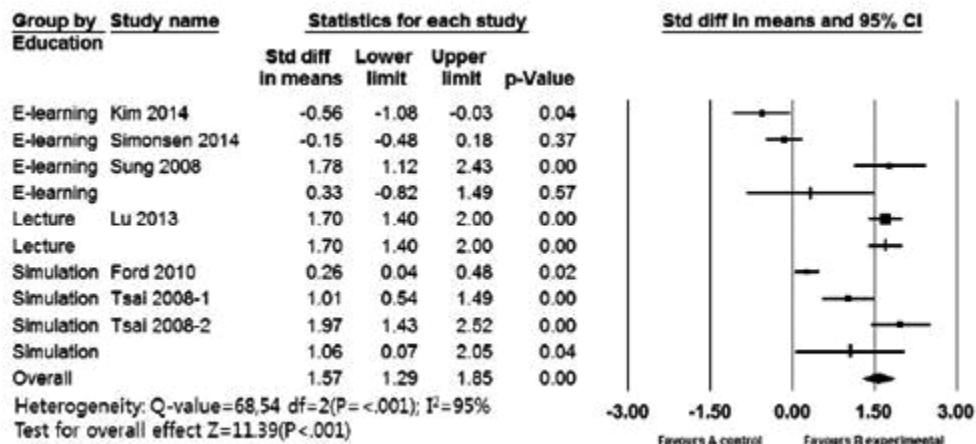


Figure 5: Effect of medication knowledge on education type of forest plot

As for the medication administration error rate, the medical device intervention (OR: 0.66, 95% CI= 0.47 to 0.93) was the only intervention type that showed statistically significant effect size. According to a preceding study, medication errors occur from

the interaction of working environment and human beings [13]. The MedMARx medication error report program of the United States Pharmacopeia reported that medication errors rarely occur from a single factor and are mostly related to compound systematic factors of the

organization [29]. When a computerized physician order entry and decision support system was implemented in neonatal wards to improve medication dosage errors, medication errors were reduced by 34% [30]. As such, introduction of medical devices or systems in the medication process is a useful intervention that can reduce medication errors.

Based on the analysis of medication knowledge, simulation (SMD: 1.06, 95% CI= 0.07 to 2.05) was the only education method that showed statistically significant effect size. Practical education based on simulation offers a learning environment that is more realistic and interactive than lecture education, and it is recommended as an education method appropriate for cultivating the decision-making ability, communication ability and work performance [31, 32]. In addition, it is evaluated as an effective education method that can foster practical and clinical knowledge in nurses that facilitate their adaptation to nursing practice through acquisition of core competencies in a safe educational environment that does not inflict harm on patients. Simulation develops integrative abilities to accommodate for different situations instead of simply acquiring knowledge and skills.

**Strengths and Limitations:** Considering strong heterogeneity among studies, the outcome variables were divided into the medication administration error rate calculated as an odd ratio and medication knowledge calculated as a standardized mean difference. This secured homogeneity among the outcome variables, setting the direction of intervention effects to agree with the direction of effect size.

Also, whereas previous studies simply reported the effects of medication error interventions, this study verified that medical device interventions are more useful than education interventions in reducing the medication error rate. Among education interventions, simulation was found to be more effective than e-learning and lecture. These results can be used as the grounds for the development of medication error prevention programs by verifying characteristics of interventions through meta-analysis.

On the other hand, this study has a limitation in determining whether the intervention effects between the intervention group and control group are purely based on interventions because there were more NRCT used for meta-analysis than RCT.

## Conclusion

Medical device interventions were useful methods of directly reducing the medication administration error rate of nurses during the medication administration process. To improve medication knowledge of nurses, simulation was an effective education method of practicing situations similar to the reality. The results of this study can be widely applied to select useful interventions that can increase quality of patient safety in the nursing scene.

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**Source of Funding:** Self

**Conflict of Interest:** Nil

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