Effect of Computerized Physician Order Entry and Clinical Decision Support System on Adverse Drug Events Prevention in the Emergency Department: A Systematic Review

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Abstract

Objective: An adverse drug event (ADE) is an injury resulting from a medical intervention related to a drug. The emergency department (ED) is a ward vulnerable to more ADEs because of overcrowding. Information technologies such as computerized physician order entry (CPOE) and clinical decision support system (CDSS) may decrease the occurrence of ADEs. This study aims to review research that reported the evaluation of the effectiveness of CPOE and CDSS on lowering the occurrence of ADEs in the ED. **Data Sources:** PubMed, EMBASE, and Web of Science databases were used to find studies published from 2003 to 2018. The search was conducted in November 2018. **Study Selection and Data Extraction:** The search resulted in 1700 retrieved articles. After applying inclusion and exclusion criteria, 11 articles were included. Data on the date, country, type of system, medication process stages, study design, participants, sample size, and outcomes were extracted. **Data Synthesis:** Results showed that CPOE and CDSS may prevent ADEs in the ED through significantly decreasing the rate of errors, ADEs, excessive dose, and inappropriate prescribing (in 54.5% of articles); furthermore, CPOE and CDSS may significantly increase the rate of appropriate prescribing and dosing in compliance with established guidelines (45.5% of articles). **Conclusion:** This study revealed that the use of CPOE and CDSS can lower the occurrence of ADEs in the ED; however, further randomized controlled trials are needed to address the effect of a CDSS, with basic or advanced features, on the occurrence of ADEs in the ED.

Keywords

adverse drug event, clinical decision support system, computerized physician order entry, emergency department, patient safety

Introduction

An adverse drug event (ADE) has been defined by the Institute of Medicine as “an injury resulting from a medical intervention related to a drug (p. 33).”¹ A medication error is an error that may occur at any stage of the drug administration process. An ADE is generally classified into 2 categories: preventable and unpreventable.² Reactions to medications such as idiosyncratic, allergic, and pseudoallergic medications are examples of unpreventable ADEs, and cytotoxic reactions, drug interactions, and some medication errors are examples of preventable ADEs.^{2,3} An ADE is a common cause of morbidity leading to hospital admissions, especially in the emergency department (ED).⁴ ADEs are public health and patient safety challenges that may

cause readmissions and consume resources such as money, time, human force, and equipment.⁵

Preventable ADEs are related to errors that occur during the prescribing, transcribing, dispensing, administration, and monitoring stages of the medication process. In the prescribing stage, the appropriate drug, dose, and route must be ordered. In the transcribing stage, the prescription

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must be read and interpreted correctly by pharmacists. In the dispensing stage, the correct medications must be delivered for the correct patient. In the administration stage, the 5 rights such as the right patient, right drug, right time, right route, and right dose must be followed. In the monitoring stage, patient's response to the administered medications must be assessed and documented.⁶

Approximately 1 in 3 ADEs are predictable and preventable; hence, applying appropriate and targeted prevention strategies may improve patient safety.⁷ Studies showed that the use of modern information technologies such as computerized physician order entry (CPOE) and clinical decision support system (CDSS) may decrease the occurrence of ADEs.^{8,9} CPOE is a computer program that helps health care providers enter medical orders such as admission, laboratory, radiology, medication, and referral electronically.¹⁰ CDSS is a computerized system that aids health care providers to make evidence-based clinical decisions about a particular patient at the point of care.¹¹

Applying these technology-based resources could promote clinicians prescribing electronically with CPOE systems. The use of these systems may improve efficiency and effectiveness in health care settings by eliminating those errors that may occur with handwritten orders. It has been documented that a CPOE system is an effective technology in patient safety and cost savings.^{12,13} Furthermore, it has been reported that an integrated CPOE and CDSS could help promote more appropriate medication prescribing by using basic and advanced types of systems. The basic type of CDSS may support those functionalities related to medications, including formulary decision, duplicate therapy, dosing guidance, drug allergy, and drug-drug interaction, whereas advanced type CDSS includes dosing support for renal insufficiency and geriatric patients, guidance for medication-related laboratory testing, drug-disease contraindication, and medication use guidance during pregnancy.¹⁴

The ED is a health care setting to which a patient is referred in case of an emergency.¹⁵ This department may experience challenges with providing safe care because of the high volume of patients and a higher workload. The ED is an especially vulnerable ward, with medication errors occurring in approximately 10% of visits.¹⁶ These errors may occur for various reasons, such as overcrowding, shortage of personnel, unfamiliar patients, dispensing medication without pharmacist double checks, dispensing medication by nurses without double checks, and the probability of errors in verbal order.¹⁷ CDSSs may reduce errors by using alarms and reminders.¹⁸ CDSS joined with CPOE by using reminder and alerting programs can notify providers regarding ADEs quickly and improve patient safety.¹⁹

The use of these technologies may help ED providers by providing clinical support for decision making in prescribing and decrease the occurrence of ADEs.²⁰ Review studies

regarding the effect of CPOE and CDSS applications to decrease the occurrence of ADEs have been conducted in inpatient and outpatient settings²¹ or specific hospital wards, such as the intensive care unit and pediatric ward²²; however, no study specifically reviewed the effect of CPOE and CDSS application on ADEs occurring in the ED. This systematic review aimed to fill this gap through studying the effect of CPOE and CDSS in decreasing the occurrence of ADEs in the ED.

Methods

PubMed, EMBASE, and Web of Science databases were searched to find reports written in English (from 2003 to 2018) in November 2018. We used a combination of MESH terms and keywords in the title field as follows: (drug OR medication OR prescription OR prescribing) AND (decision-support OR decision support system OR clinical decision support system OR CDSS OR CPOE OR Computerized physician order entry OR computerized provider order entry OR computerized practitioner order entry OR expert system OR drug therapy, computer-assistant OR information system).

Inclusion criteria were before-and-after and clinical trial studies to assess CPOE and CDSS in decreasing the occurrence of ADEs in the ED. Non-English articles, publications with no published abstract, and other types of articles such as conference abstracts and review studies were excluded.

All retrieved articles ($n = 1700$) were reviewed by 2 of the authors after removing duplicate articles ($n = 840$). The remaining records were screened and excluded if there was a conference abstract ($n = 154$) or no published abstract ($n = 174$) or if the study was a review ($n = 66$). The remaining articles ($n = 466$) were reviewed by title and abstract to find before-and-after and clinical trial studies that used CPOE and CDSS in decreasing the occurrence of ADEs in the ED. Finally, 11 research works were included in our study. The process of PRISMA to identify included articles is presented in Figure 1. Included studies were assessed using the following items: study date, country, type of system, study design, participants, sample size, and outcomes. Furthermore, study quality was evaluated using the Mixed Methods Appraisal Tool (MMAT)²³ via answering 5 questions for quantitative randomized controlled trials and 5 questions for quantitative nonrandomized trials by 2 of the authors.

Results

A total of 11 articles were included in this review that evaluated the effect of CPOE and CDSS on ADEs in the ED (Tables 1 and 2).^{16,24-33}

Figure 1. The process of PRISMA used to identify and include articles in the study.
Abbreviation: ED, emergency department.

Study Quality

Most of the included studies were good in terms of quality. Of 11 included articles, 5 met all MMAT criteria (2 randomized controlled trials, 2 before and after studies, and 1 cohort study). In 5 nonrandomized studies, confounder variables were not controlled, and in 1 article, inclusion and exclusion criteria to select participants were not clarified (Table 3). Findings in the included studies are presented in what follows.

Year-Oriented Analysis

Four studies (36.5%) were carried out in 2011, 3 studies (27%) in 2007, and the remaining were in 2005, 2006, 2012, and 2016.

Country-Based Analysis

Seven studies (63.5%) were performed in the United States, and the other 4 studies (36.5%) were conducted in Australia, France, Spain, and Canada.

Table 1. Details of Included Articles (Part 1).

Study	Study date	Country	System (intervention)	Medication process stage	Study design
Sard et al ¹⁶	2005	United States	CPOE with CDSS	Prescribing	Retrospective before-and-after
Buising et al ²⁴	2006	Australia	CDSS	Prescribing	Preintervention and postintervention cohort study and a time series analysis
Griffey et al ²⁵	2007	United States	CDSS	Prescribing	Prospective controlled trial
Terrell et al ²⁶	2007	United States	CPOE with CDSS	Prescribing	Randomized controlled trial
Terrell et al ²⁷	2007	United States	CDSS	Prescribing	Randomized controlled trial
Sethuraman et al ²⁸	2011	United States	CPOE with CDSS	Prescribing	Prospective before-and-after
Faine et al ²⁹	2011	United States	CPOE with CDSS	Prescribing	Retrospective before-and-after
Netherton et al ³⁰	2011	Canada	CPOE with CDSS	Administering	Retrospective before-and-after observational
Diaz et al ³¹	2011	Spain	CPOE with CDSS	Prescribing	Quasi-experimental, one-group before-and-after
Demonchy et al ³²	2012	France	CDSS	Prescribing	Prospective before-and-after controlled interventional
Kim et al ³³	2016	United States	CPOE	Administering	Before-and-after

Abbreviations: CDSS, clinical decision support system; CPOE, computerized physician order entry.

System-Based Analysis

Six studies (54.5%) evaluated CPOE with CDSS, 4 studies (36.5%) evaluated only CDSS, and 1 (9%) evaluated only CPOE.

Medication Process Stages

In 9 studies (82%), CPOE and CDSS were used in the prescribing stage, and in 2 (18%), CPOE and CDSS were used in the administration stage.

Study Design Analysis

Eight studies (73%) were observational, and the remaining 3 (27%) were control trials.

Participant Analysis

In 9 reviewed studies (82%), only patients were involved, and in 2 (18%), both patients and emergency medicine physicians participated.

Sample Size Analysis

Of 11 reviewed studies in which only patients were participants, 6 studies (54.5%) had less than 1000 samples, 2 studies (18%) had between 1000 and 2000 samples, and 3 studies (27%) had more than 2000 samples. Of 2 studies in which physicians also were participants, one had 42 and the other had 63 samples.

Outcome Analysis

Sard et al¹⁶ evaluated the effect of CPOE with CDSS to prevent prescribing errors in a pediatric ED. This study showed that the rate of errors per 100 visits decreased significantly from 24 errors before the intervention to 13 errors after the intervention (Incidence Rate Ratio (IRR) = 0.54; 95% CI = 0.39-0.76; *P* value = 0.0003).

Buising et al²⁴ evaluated the impact of CDSS on the rate of appropriate antibiotic prescribing for adults with pneumonia in the ED. This study showed that the rate of concordant prescribing increased 21.5% in the computerized decision support period when compared with the academic detailing period (odds ratio = 2.03 [1.13, 3.66]; *P* value = 0.01).

Griffey et al²⁵ evaluated the impact of CDSS on ADEs in the older ED. This study showed that the rate of ADEs significantly decreased from 31 (7.1%) in off periods to 8 (3.4%) in on periods (*P* value = 0.02).

Terrell et al²⁶ evaluated the effect of CPOE with CDSS on the rate of excessive medication dosing for patients with renal insufficiency. This study showed that physicians in the intervention group prescribed medications significantly less compared with control physicians (43% vs 74%; effect size = 31%; 95% CI = 14%-49%; *P* value = 0.001).

Terrell et al²⁷ evaluated the effect of CDSS on the rate of inappropriate prescribing in older ED patients. This study showed that the rate of inappropriate prescribing was significantly decreased, from 5.4% to 3.4% (OR = 0.59; 95% CI = 0.41-0.85; *P* value = 0.006).

Sethuraman et al²⁸ evaluated the effect of CPOE with CDSS on the rate of prescription error in a pediatric ED. This study showed that the rate of prescription error

Table 2. The Details of Included Articles (Part 2).

Study	Participants	Sample size	Outcomes
Sard et al ¹⁶	Pediatric patients	N total patient visits = 840 (n before = 420; n after = 420)	The rate of errors: 24 to 13 errors per 100 visits ($P = 0.0003$)
Buising et al ²⁴	Patients	N total = 133	The rate of concordant prescribing: 21.5% increase in the CDSS period compared with the academic detailing period ($P = 0.01$)
Griffey et al ²⁵	Patients ≥ 65 years old	N total = 1407 (n case = 739; n control = 668)	The rate of ADEs: 31 (7.1%) to 8 (3.4%) $P = 0.02$
Terrell et al ²⁶	Emergency medicine faculty and resident physicians, patients ≥ 18 years old	<ul style="list-style-type: none"> N total physicians = 42 (n case = 21; n control = 21) N total patient visits = 2783 (n case = 1493; n control = 1290) 	The rate of excessive medication dosing: 74% to 43% ($P = 0.001$)
Terrell et al ²⁷	Emergency physicians, patients ≥ 65 years old	<ul style="list-style-type: none"> N total physicians = 63 (n case = 32; n control = 31) N total patient visits = 5162 (n case = 2647; n control = 2515) 	The rate of inappropriate medications: 5.4% to 3.4% ($P = 0.006$)
Sethuraman et al ²⁸	Patients ≤ 18 years old	N total = 10 000 (n before = 5000; n after = 5000)	The rate of prescription error: 8 to 5.4 per 100 visits ($P < 0.0001$)
Faine et al ²⁹	Patients	N total = 278 (n before = 100; n after = 178)	The rate of appropriate dose: 24.0% to 34.3% ($P = 0.07$)
Netherton et al ³⁰	Patients with renal colic	N total = 436 (n before = 206; n after = 230)	The proportion of patients receiving appropriate prescribing significantly increased after CPOE implementation: 65.6% to 76.5% ($P = 0.015$)
Diaz et al ³¹	Patients ≥ 18 years old with an estimated glomerular filtration rate < 60 mL/min	N total = 171	The rate of appropriate prescribing based on renal function: 65% to 86% ($P < 0.001$)
Demonchy et al ³⁰	Patients ≥ 15 years old	N total = 912 (n period 1 = 317; n period 2 = 348; n period 3 = 247)	The rate of appropriate antibiotic prescriptions: In only 1 ED 33% to 53% ($P = 0.007$)
Kim et al ³³	Patients ≥ 65 years old	N total = 1946 (n before = 1002; n after = 944)	The rate of appropriate dose: 27.3% to 32.5% ($P < 0.001$)

Abbreviations: ADE, adverse drug event; CDSS, clinical decision support system; CPOE, computerized physician order entry; ED, emergency department.

significantly decreased in drug dose errors per 100, from 8 to 5.4 (95% CI = 1.7-3.3; P value < 0.0001).

Faine et al²⁹ evaluated the effect of CPOE with CDSS on the rate of inappropriate dosing in the ED. This study showed that the rate of inappropriate dosing significantly decreased from 34.3% to 24% (P value = 0.07).

Netherton et al³⁰ evaluated the impact of CPOE with CDSS implementation on analgesic prescribing and dosing for renal colic in the ED. This study showed that prescribing ketorolac instead of opioids significantly increased after CPOE implementation, from 65.6% to 76.5% (P value = 0.015).

Diaz et al³¹ evaluated the effect of CPOE with CDSS on the rate of appropriate prescribing based on renal function in the ED. This study showed that the rate of appropriate prescribing significantly increased from 65% before to 86% after the intervention (P value < 0.001).

Demonchy et al³² evaluated the impact of CDSS on compliance with guidelines on antibiotics prescribed for urinary tract infections in the ED. This study showed that CDSS significantly improved the compliance of antibiotic prescriptions with guidelines in 1 ED (increase = 20%; P value = 0.007).

Kim et al³³ evaluated the effect of CPOE on the rate of prescribing doses of high-risk medications in older ED patients. This study showed that the rate of recommended dose significantly increased in all medications of interest from 27.3% to 32.5% (P value < 0.001).

Generally, the percentage of reduction in the rate of prescribing errors, ADEs, excessive doses, and inappropriate prescribing in 6 articles was from 2% to 31%. Also, the percentage of increase in the rate of appropriate prescribing and dosing and compliance with established guidelines was from 5.2% to 21.5%.

Table 3. Quality Assessment of Included Studies.

Study	Quantitative randomized controlled trials					Quantitative nonrandomized				
	Appropriate randomization	Comparable groups at baseline	Complete outcome data	Assessors blinded to the intervention	Participants' adherence to the intervention	Participants representative of the target population	Appropriate measurements for the outcome and intervention	Complete outcome data	Confounders accounted for in the design and analysis	Administered intervention
Sard et al ¹⁶						Y	Y	Y	Y	Y
Buising et al ²⁴						Y	Y	Y	Y	Y
Griffey et al ²⁵						Y	Y	Y	N	Y
Terrell et al ²⁶	Y	Y	Y	Y	Y					
Terrell et al ²⁷	Y	Y	Y	Y	Y					
Sethuraman et al ²⁸						Y	Y	Y	N	Y
Faine et al ²⁹						Y	Y	Y	Y	Y
Netherton et al ³⁰						Y	Y	Y	N	Y
Diaz et al ³¹						Y	Y	Y	N	Y
Demonchy et al ³²						Y	Y	Y	N	Y
Kim et al ³³						N	Y	Y	Y	Y

Abbreviations: N, no; Y, yes.

The CDSS Properties

In this review, 10 of 11 studies (91%) used CDSS; 9 studies used dosing guidance, 4 used drug-allergy checking, 3 used formulary decision, 3 used drug interaction, and 2 used duplicate therapy of basic properties of CDSS. Advanced properties were used in 8 studies, of which 4 related to dosing support for renal insufficiency and geriatric patients, 3 related to guidance for medication-related laboratory testing, and 1 related to a drug-disease contraindication. Medication use guidance during pregnancy property had not been provided in any study (Table 4).

Discussion

This systematic review assessed 11 investigations conducted on decreasing the occurrence of ADEs in the ED by using CPOE and CDSS. Results showed in all studies that the use of CPOE and CDSS could decrease the number of ADEs significantly by reducing errors during the prescribing of medications and increase compliance of prescribing in line with published guidelines. The other review studies using CPOE and CDSS to detect and prevent medication errors and ADEs showed that using these systems in health care settings could have effective results.³⁴⁻³⁶

Results also showed that 63.5% of the studies were performed in the United States. This may be because the rate of ADE admissions (6.82% of total) and cost that is imposed on the United States economy is high, and every year it goes higher.³⁷

Eight of the studies were observational, and only 3 were control trials. Although clinical trial studies are the best studies to evaluate the impact of a new therapeutic approach, the use of these types of studies on the impact of CPOE and CDSS was limited. This may be a result of the fact that clinical trial studies are time-consuming and expensive and must be conducted under certain conditions. This result is consistent with the review study that assessed the effect of these systems on the rate of occurrence of ADEs.⁹

CPOE systems, especially with CDSS, could be used in all 5 stages of the medication process; the results of this study showed that CPOE and CDSS in the ED were only used in prescribing and administration stages of the medication use process. In addition to CPOE and CDSS, there are several strategies to prevent ADEs in the various stages of medication processes, such as automated dispensing cabinet and barcode medication system.¹⁷ Whereas the results of this study showed that the use of CPOE and CDSS significantly prevents ADEs in prescribing and administration stages, other studies showed that the use of these systems may also significantly reduce ADEs in transcribing¹⁷ and dispensing³⁸ stages. It is suggested to develop and apply these systems in the transcribing and dispensing stages in the ED because of the significant effect in reducing ADEs.

Although the use of basic and advanced properties of CDSS has many benefits, particularly in reducing errors by preventing inappropriate drug prescribing and inappropriate dose prescribing and also especially in pregnant, renal insufficiency, geriatric, and pediatric patients, results showed that use of these properties is low. The dosing guidance basic feature of CDSSs was used in most

Table 4. Type of CDSS Used Based on Basic and Advanced Classifications.

Study	Basic					Advanced			
	Formulary decision	Duplicate therapy	Dosing guidance	Drug allergy checking	Drug-drug interaction	Dosing support for renal insufficiency and geriatric patients	Guidance for medication-related laboratory testing	Drug-disease contraindication	Medication use guidance during pregnancy
Sard et al ¹⁶	✓	✓	✓	✓	✓	—	—	—	—
Buising et al ²⁴	—	—	—	✓	—	—	✓	—	—
Griffey et al ²⁵	✓	—	✓	—	—	✓	—	—	—
Terrell et al ²⁶	—	—	✓	—	—	✓	✓	—	—
Terrell et al ²⁷	—	—	✓	—	—	✓	—	—	—
Sethuraman et al ²⁸	—	✓	✓	✓	✓	—	—	—	—
Faine et al ²⁹	—	—	✓	—	—	—	—	—	—
Netherton et al ³⁰	—	—	✓	—	—	—	—	—	—
Diaz et al ³¹	✓	—	✓	✓	✓	✓	✓	✓	—
Demonchy et al ³²	—	—	✓	—	—	—	—	—	—

Abbreviation: CDSS, clinical decision support system.

studies.^{16,25-32} Dosing support for renal insufficiency and geriatric patients is the most used strategy in the advanced feature.^{16,25-32} This may be because of the probability of error occurrence in the prescribed dose in the ED as a result of high overcrowding. Attention to drug allergies and drug interactions for prescribing appropriate drugs, especially in the ED, it being the primary part of the health care setting that a patient is referred to in an emergency, can prevent ADE occurrence; however, these basic features of CDSSs were used in a small number of included studies. Pregnancy is one of the conditions where appropriate drug prescribing needs to be considered carefully. In pregnancy, some drugs are contraindicated; therefore, drugs should be prescribed with caution. Using CDSS in this situation, which reminds the physician that the patient is pregnant, could prevent ADEs, which can be dangerous for both the mother and the fetus.

Considering the results of studies that showed CPOE and CDSS systems could reduce ADEs and medication error occurrence in hospital settings,³⁴⁻³⁵ these systems should be used widely to help physicians making the right decision in medication prescription and avoid adverse event incidence. The CDSS notifies the physician by providing an alert message when the life of the patient is threatened by inappropriate prescription. Designing these systems is very important

to encourage physicians to use them. The existence of non-specific alerts that lead to alert fatigue and then a high rate of alert override is one of the main problems in the widespread use of CDSSs.³⁹ Designing an on-demand and customizable decision support system may solve the alert fatigue problem.⁴⁰

To our knowledge, this is the first review study that specifically assesses the effect of CPOE and CDSS application on decreasing the occurrence of ADEs in the ED. This study has limitations, which are as follows. As the search in “all fields” or “title and abstract” fields resulted in many research works, we restricted our search to the “title” field. Therefore, some related studies were not found in our search result, and we added 4 articles from the references review of included research studies. The analysis of this study was limited to a descriptive analysis, and the meta-analysis was not carried out because there was no homogeneity in the study design and outcomes measures of included articles. Differences between home-ground and commercial CPOE and CDSS systems were not considered in this study.

Although studies showed enough evidence to suggest that the use of CPOE and CDSS in the ED could prevent ADEs, further randomized controlled trials are needed on CDSSs with basic and advanced features.

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