A SYSTEMATIC REVIEW ON THE STRATEGIES AND TECHNIQUES FOR DECREASING PRESCRIBING ERRORS

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ABSTRACT

Prescribing errors can lead to tragic consequences in the modern health care systems. The prescribing process faces many barriers that cause limitations, such as information and communications technology (ICT) shortcomings, high workload, complex polypharmacy, patient factors, lack of standardization, and frequent rotations of inexperienced physicians on the wards. Therefore, several strategies and tools were introduced to face this problem, including computerized physician order entry (CPOE), education and training of the prescribers, and expanding the role of the clinical pharmacist. In this systematic review, we are going to address the studies which discussed the different strategies to minimize the prescribing errors. Also, the outcomes and the limitations of each strategy will be discussed throughout this review. Because of the limitations of the application of each strategy separately, it is concluded that the integration between them can lead to overcoming each technique's drawbacks and enhance the decrease in the prescribing errors.

Keywords: Prescribing errors, Prevention, Strategy, CPOE, Education, Pharmacist intervention.

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INTRODUCTION:

Medication errors and adverse drug events represent a tragic problem to modern healthcare systems. Medication errors can be broadly classified as prescribing, dispensing or drug administration errors. Medication errors injure 1.5 Million people a year in the USA, and drug-related injuries occurring in hospitals alone cost \$3.5 billion annually.¹ The degree of severity of medication errors according to the national coordinating council for medication error reporting and prevention can range from minor errors to fatal mistakes that can lead to patient's death.² Accordingly, medication errors are accounted to be the seventh most common cause of death in general.³

In this context, prescribing errors could be accounted as the most prevalent type of the medication error.⁴ In general, prescribing errors may be defined as the wrong drug selection for a patient.⁵ These errors involve: prescription omissions or inaccurate allergy information; improper or omitted dose; omitted route of administration; improper or omitted frequency; medication omission; incorrect medication or unspecified medication; duplication; drug/allergy interaction; wrong formulation; potential drug/drug interaction; drug/food interaction; unauthorized drug; incorrect treatment duration; illegible order.⁶

The prescribing process faces many barriers that cause limitations, such as high workload, lack of experience of the prescribers, information and communications technology (ICT) shortcomings, complex polypharmacy.⁷ Therefore, it is necessary to understand the causes that contribute to prescribing errors, in order to be able to address these factors. Fig. 1 summarizes the causes of prescribing errors.⁸

Fig 1. Causes of prescribing errors framework.⁸

In the recent years, different strategies and tools have been introduced in order to minimize or prevent the prescribing errors. Most studies suggested the introduction of Computerized Physician Order Entry (CPOE) to reduce the prescribing errors, but on the other side, other studies suggested unintended negative consequences of the application of this strategy in preventing the prescribing errors. The second most addressed strategy is the Educational Initiatives which are intended to prevent the occurrence of prescribing errors especially and the medication errors in general. Education strategies include group training sessions, individual educational visits, letters and printed materials, auditing and error reporting systems, as well as improvement projects. However, some studies concluded that this intervention didn't affect the prescribing error rates and the variation in the programs of training as well as the basic knowledge and education of the prescribers vary between the different studies. The third intervention is focused on extending the professional roles, group education sessions, and integration of the clinical pharmacists in the prescribing process for the beneficence of the patients and the prevention of prescribing errors. However, this strategy should be integrated with the other strategies for minimizing the rates of prescribing errors.

Therefore, the main objective of this review article is to address the different strategies (techniques) and tools for minimizing prescribing errors. Furthermore, this review aims to discuss the most powerful strategy for controlling these errors and overcome the limitations of the application of each strategy.

METHODS:

I- Research methodology

The Systematic Literature Review (SLR) aims to identify, evaluate, and interpret the literature related to a specific research topic area or question. As the most critical pre-review activity in SLR is to define the Research Questions (RQ) that drive the entire research methodology, in this systematic review, we are going to answer the following questions:

RQ1: What are the strategies and tools used in minimizing the prescribing errors?

RQ2: What is the study design applied in each study?

RQ3: What are the outcomes of the application of each strategy?

RQ4: Which is the concluded strategy that can lead to almost prescribing errors prevention?

Fig.2 The process flow for the survey methodology.

The stages involved in carrying out SLR are: a) identification of resources, (b) selection of studies, and (c) data extraction and synthesis. First, the identification of resources defines the preliminary searches aimed to assess the volume of potentially relevant studies in the literature resulting in the INITIAL LIST, which contains all the articles matching the search criteria. Then, the main objective of the selection of the studies is to filter the articles in the INITIAL LIST according to several exclusion criteria resulting in the FINAL LIST, which contains all the articles included in our review. Finally, data extractions and synthesis define the extracted data, which were analyzed from each article in the FINAL LIST. Fig. 2 summarizes the process flow for the survey methodology to be discussed in details in the following sections.

II- Identification of resource

Recognizing the relevant keywords plays a pivotal role in resource identification process. Therefore, an extensive search using (the keywords: “Prescribing error” AND “prevention” AND “intervention” AND “Strategy”) as a query text is conducted within the most prominent scientific digital libraries (PubMed and Science Direct). The search is carried out using the following criteria: (1) Articles are published in a reliable peer-reviewed journal or conference; (2) Articles are published between 2000 and 2018; (3) Articles are written in English.

Based on the aforementioned search criteria, a total of 251 articles have been found. These articles are stored in the INITIAL LIST.

III- Selection of studies

Various ways of selection are suggested in the existing systematic review. In this work, several exclusion criteria are considered and they can be summarized as follows:

- The first rule is to exclude the articles that were not clearly related to the research questions. Articles were only kept for further processing if the contents

explicitly mention that the main focus of the article is strategies in the prevention of prescribing errors.

- The second rule is to exclude the duplicate articles.
- The remaining articles were subjected to a quality screening such that the articles that did not meet the following quality criteria (QC) are eliminated:

QC1: Is the aim of the research clear?

QC2: Is the proposed strategy feasible?

QC3: Are the results completely analyzed and explained?

QC4: Is the overall quality of the writing good?

QC5: Is the information in the paper sound factual and accurate?

All the articles were examined by answering YES/MAYBE/NO to specify either each criterion was met or not. Then, a score for each article is calculated by giving one point for each “YES” 0.5 points for each “MAYBE” and zero points for each “NO” the article that achieved a score less than 3 points is excluded from the final list used in our review.

Based on our exclusion criteria, 33 articles were selected and stored in the FINAL LIST. All results and discussions provided in this work were extracted from the studies included in the FINAL LIST.

IV- Data extraction and synthesis

The data extracted from each article in the FINAL LIST were as follows:

- The source (journal and conference) and year of publication.
- Full reference.
- Author’s information.
- The study setting.
- The study design.
- The intervention and strategy applied to decrease the prescribing error.
- The outcome of the application of the different strategies on the prescribing error percentage.
- The results and conclusion.

The extracted data was analyzed as per the used terminologies, methods and objectives to categorize the articles in the FINAL LIST. In general, the strategies applied for the prevention of prescribing errors were classified into 3 main strategies: 1) The Computerized Physician Order Entry (CPOE), 2) Education and training of the prescriber, and (3) Pharmacist intervention.

RESULTS AND DISCUSSION:

In this section, we are going to discuss the studies that addressed each strategy in separate sub-sections, in addition to the study setting, the study design, the intervention (strategy or technique) applied and the outcome of this intervention. Table 1 summarizes the related work addressing the three strategies (CPOE, prescriber education and training, and pharmacist intervention) and their effect on decreasing the prescribing errors.

I- Computerized Physician Order Entry (CPOE):

The implementation of CPOE in the prescribing process and their impact on minimizing the prescribing errors in the hospital settings is largely discussed in a substantial number of studies in the literature. It was clear that it significantly resulted in improving the prescribing process and the treatment plan.^[9-21]

These studies addressed different tools in the application of CPOE. For instance, Amato et al reviewed a convenience sample of 10 CPOE systems at 6 sites were evaluated. These

included both inpatient and outpatient systems, and in-house-developed as well as commercial systems, at academic medical centers, a large managed care organization, and a multispecialty community group practice. In the first phase of the study, the Computerized Prescriber Order Entry Medication Safety (CPOEMS) team assessed the CPOE systems' features and identified problematic issues with medication ordering display and workflow. The second phase of the study involved a review of several different sources of information, including safety and adverse event or error reports, at each of the sites. All available error reports from the 6 sites were collected and reviewed to identify reports of medication errors that occurred in the ordering phase of the medication use process and analyze which errors could be classified as CPOE-related.⁹ Gouyon et al applied the use of neonatal C.P.O.E./C.D.S. system for all prescriptions of all hospitalized newborns over an 18-month period. The preselected prescription of drugs was based on the indication, gestational age, body weight and post-natal age. The therapeutic protocols were provided by a formulary reference (330 drugs) that had been specifically designed for newborns. The preselected prescription also gave complete information about preparation and administration of drugs by nurses. The prescriber was allowed to modify the preselected prescription but alarms provided warning when the prescription was outside the recommended range. The main clinical characteristics and all items of each line of prescription were stored in a data warehouse, thus enabling this study to take place.¹⁰

Hitti et al compared the error rates in a randomly selected sample of discharge prescriptions (handwritten versus electronic) five months pre and four months post the introduction of the E-prescription. The internally developed, E-prescription system included a list of 166 commonly prescribed medications with the generic name, strength, dose, frequency and duration. A total of 2,883 prescriptions in this study: 1,475 in the pre-intervention phase were handwritten (HW) and 1,408 in the post-intervention phase were electronic. The rates of 14 different errors were calculated and compared between the pre- and post-intervention period.¹¹

On the other hand the CPOE strategy was widely used in the oncology practice especially when prescribing the cytotoxic chemotherapies and the supportive treatment. For example, Elsaid et al reported the development of chemotherapy regimen-specific prescribing templates. Following entry of the patient's data (eg, height, weight, serum creatinine), chemotherapy doses were automatically calculated. Prescribers were able to select the dosing intensity of any chemotherapy drug from a list of pre-specified evidence-based dosing levels. Additionally, a dose adjustment level was preprogrammed into the prescribing module and the adjusted dose was automatically calculated. The prescribing module also contained supportive care instructions as well as administration instructions. Completed chemotherapy prescriptions were automatically sent to the pharmacy for validation and preparation of chemotherapy.¹⁵

Small et al reported the implementation of commercially available oncology prescribing software in an ambulatory care setting. Prior to implementation of the prescribing software, customization of prescribing templates and menus was performed by specialist oncology pharmacists in the institution. While the oncology prescribing software was equipped with Clinical Decision support (CDS) features including dose calculations, adjustments, and alert generation, the software did not interface with other patient health record systems in the hospital.¹⁶ Meisenberg et al adopted a quasi-experimental sequential study design to compare handwritten orders, preprinted orders, and CPOE orders over a 5-year period for the frequency of problems or errors in chemotherapy orders.¹⁷ Harshberger et al evaluated the impact of chemotherapy electronic prescribing using Electronic health record (HER)/CPOE on completeness of regimen documentation for six chemotherapy regimens and clinical staff satisfaction.¹⁸

On the other side, HuertasFernández compared prescription error rates in handwritten versus computerized chemotherapy prescriptions using a concurrent observational study design.¹⁹ Voeffray et al described the development of a prescribing module directly connected to a standardized chemotherapy regimen database. Upon entry of the patient's data (eg, height, weight, serum creatinine) by the physician, chemotherapy doses were automatically computed. The prescribing module allowed dose modification and required physicians to enter a reason for dose modification.²⁰ Kim et al described their organization's approach to modify a CPOE system to allow prescribing of a complex chemotherapy regimen through programming of pre-specified order sets. These regimen-specific order sets list standardized chemotherapy doses and allow the prescribing of adjunctive supportive care treatments. The CDS features included dose calculations and adjustment based on relevant patient data and clinical laboratory values.²¹

Investigators observed a significant reduction in the probability of order problems and errors when the institution switched to using preprinted order forms from handwritten orders. Additionally, a significant reduction in order problems and errors was observed in CPOE-generated orders compared with preprinted order sets. The use of CPOE completely eliminated problems and errors related to missing patient identifiers and data, and erroneous dose calculations.^[9-21]

However, other studies have identified problems related to the involvement of CPOE and clinical decision support (CDS), including the navigation between multiple screens, the confusion of data labels, miss-selection errors, erroneous suggestions of medications and doses.^{22,23} In addition to other errors including, non-intuitive ordering or information transmission, Lack of standardized terminology, interoperability issue, duplicate prescriptions, and repetition of previously corrected errors, reduced visibility of computerized errors.^{11,22} Also, it can lead to a lack of knowledge about the CDS checks that are being performed, inconsistent and insufficient use of CDS to safeguard against errors.^[22-25]

II- Education strategy:

The implementation of an educational intervention, is a simple and low-cost strategy that could produce a significant reduction of the prescription error rate. Most studies discussed the educational strategy to cause a significant reduction in prescribing errors.

The percentage of decrease in the errors, as well as the application of educational strategies vary greatly between different studies.^[26-37] For instance, Rogers et al reviewed adverse drug events (ADEs) reported through a voluntary event reporting system to determine the number and types of immunization errors. During the prescribing phase of the medication-use process, 57% (43 of 75) of errors occurred. First, age-based restrictions were implemented within the Electronic Medical Record. This was followed by mandatory immunization education for all prescribers working in the primary care network. Data collection included all reported vaccine errors within the voluntary event reporting system and completion rates of education by physicians, nurse practitioners, and medical residents.²⁶

Foster et al provided education on good prescribing/ED medication and prescription errors, followed by daily feedback on patient cases and therapy.²⁷ Trivalle et al suggested education on ADEs and relevant pharmacotherapy in elderly.²⁹ Another study discussed the use of a medication order chart, education on good prescribing and feedback on prescription errors of physicians, provision of dosing assistance.³⁰ Martinez-Anton et al, proposed Standardization of prescription sources, update of protocols, education on good prescribing.³⁴ on the other hand studies addressed the educational strategy in the ICU department, post cardiac surgery templated physician order, systematic physician education, and in the Emergency Department.^[35-37] Thomas et al addressed the difference between the types of education and compared between online education and high-intensity education.²⁸

From these studies, it is noted that improvement appears related to an important modification of the behavior of health professionals during drug prescription. On the other side, it should be noted that the initial prescribing error rates vary between different studies.

Although education strategy can enhance the prescribing error percentage^[26,27 and 29-36], but some studies revealed that it didn't cause any significant change in prescribing errors.^{28,}

³⁷The content of the educational programmes and the way of providing the education varied considerably. Different definitions of prescribing errors and ADEs were used, contributing to a large variation in the percentages found. This large variation might also be explained by the difference in the study settings and in the prescribers targeted in the intervention. It has been suggested that the prevention of patient harm is likely to require complex, multifaceted intervention strategies. Education should be embedded in a broader array of measures aimed at appropriate prescribing. Although it is plausible that patients will benefit from educating hospital prescribers in pharmacotherapy, but still further work is needed to develop effective educational interventions and to perform robust evaluations.³⁸

The knowledge of how to teach effectively should be combined with optimizing the content of the education. As well, there is no data supporting a specific form of education and training. In addition, studies suggested that educational programmes need a follow-up, to enhance learning retention. Most studies pointed to the importance of combining education with different strategies in a multifaceted intervention to obtain a real improvement in prescription quality. In addition, the qualifications or training of teachers who deliver the educational interventions was rarely addressed in the included studies. This could also have influenced the quality of the intervention and the outcomes.

III- Pharmacist intervention

Studies of expanding professional roles tend to focus on how pharmacists can identify any error before patients are harmed including checking for errors as prescriptions are received at the pharmacy or in the wards, medicine reconciliation or reviews, in addition to individual or group education sessions.

Most studies suggested that engaging pharmacists in these ways can be beneficial, but few studies have explored the best ways to integrate pharmacists into teams and the inter-professional factors to be considered.^[39-46]

The intervention of the pharmacist differs between the studies, for example, Kaushal et al addressed full-time pharmacists participation in physician rounds and provided physicians with timely information and advice on ADEs; drug interactions; and appropriate dosages, dose intervals, and routes of administration.³⁹ Klopotoska et al reviewed the interventional role of two hospital pharmacists with 10 years of experience who completed 4 weeks of training in the ICU before the start of this study to guarantee the quality of intervention. ICU hospital pharmacist reviewed medication orders for patients admitted to the ICU, noted issues related to prescribing, formulated recommendations and discussed those issues during patient review meetings with the attending ICU physicians.⁴⁰ Lee et al discussed the participation of ICU pharmacist in the collaborative therapeutic management of patients during ICU interdisciplinary medicine rounds, performed chart reviews, and made recommendations.⁴¹ Ranchon et al and Barakat et al studied the effect of the correlation between some risk factors and the prescribing errors in the oncology department for the prediction of the potential errors and the prevention of their future occurrence.^{41,43} Chamoun et al proposed that documentation could be completed by pharmacy students on infectious diseases and cardiology rotations then reviewed by clinical pharmacists with respective specialties. Before data analysis, a new pharmacy reporting sheet was developed in order to link interventions according to medical related problems (MRP). Then, MRPs were grouped into five main medication errors (ME) nodes. Haseeb et al considered the pharmacist

intervention through a series of interactive lectures delivered by an experienced clinical pharmacist to all hospital staff members and dissemination of educational tools (flash cards, printed list of high-risk abbreviations (HRAs), awareness posters) designed in line with the recommendations of the Institute for Safe Medical Practices and the US Food and Drug Administration.⁴⁶

From these studies, we can conclude that the pooled analysis supported the role of pharmacists in reducing preventable ADEs and prescribing errors. Because, these studies show different methods of interventions by the clinical pharmacists to decrease the prescribing errors, in addition to the promising effects of the expansion of the role of the pharmacist in the prescribing process and the pharmacist's interventions due to CPOE for decreasing the prescription errors. But it is clearly obvious that this strategy should be correlated with the previously addressed strategies to achieve minimal prescribing error rates.

Table 1. The related work addressing the three strategies (CPOE, prescriber education and training, and pharmacist intervention) and their effect on decreasing the prescribing errors.

Study	Study setting	Study design	Type of intervention (strategy)	Outcome of the intervention
Amato et al, 2017 ⁹	6 sites participating in a United States Food and Drug Administration	Review study	CPOE	Of 2522 medication error reports, 1308 (51.9%) were related to CPOE. Of these, CPOE facilitated the error in 171 (13.1%) and potentially could have prevented the error in 1137 (86.9%).
Gouyon et al, 2017 ¹⁰	29 bed neonatal ward	Pilot study	CPOE	About 30.4% of neonates had at least one out of licensed prescription; A prescription out of the recommended range for daily dose was recorded for 1.0% of all drug prescriptions.
Hitti et al, 2017 ¹¹	ED of the American University of Beirut Medical Center	pre- and post-intervention study	CPOE	E-prescriptions reduced missing dose (11.3% to 4.3%), missing frequency (3.5% to 2.2%), missing strength errors (32.4% to 10.2%) and legibility (0.7% to 0.2%). E-prescriptions, however, were associated with a significant increase in duplication errors, specifically with home medication (1.7% to 3%).
Aziz et al, 2015 ¹²	30-bed chemotherapy bay of a tertiary	A prospective study	CPOE	The incidence of medication errors was significantly lower in the Computerized physician order entry of

	hospital.			chemotherapy order compared with the paper-chemotherapy order (10/3765 [0.26%] versus 134/5514 [2.4%]).
M. Sanchez et al, 2015 ¹³	Pharmacy Department of the Hospital Ramon y Cajal (Madrid, Spain)	prospective analytical study	CPOE	The total number of MEs per 100 patients decreased from 236.8 to 10.9, with an absolute risk reduction of 36.2. The percentage of prescriptions with ME decreased from 37.5% to 1.2%.
Colins et al, 2010 ¹⁴	719-bed multidisciplinary tertiary care institution with a pediatric division and an outpatient cancer center	Pre- and post-cohort study	CPOE	CPOE implementation significantly reduced prescribing error risk by 69%.
Elsaid et al, 2013 ¹⁵	700-bed multidisciplinary tertiary care hospital with an ambulatory cancer center	A quasi-experimental	CPOE	30% reduction in prescribing errors was observed with initiating the intervention.
Small et al, 2008 ¹⁶	Ambulatory setting in the UK	Prospective study	CPOE	Computerized prescribing reduced errors by 42%. Errors occurred in 20% of spreadsheet prescriptions compared with 12% of the computerized prescriptions.
Meisenberg et al, 2013 ¹⁷	Period Mixed ambulatory patients and inpatients in the USA	Quasi-experimental	CPOE	Reduction from 30.6% with handwritten orders to 12.6% with preprinted orders to 2.2% with CPOE. The incidence of errors capable of causing harm was reduced from 4.2% with handwritten orders to 1.5% with preprinted orders to 0.1% with CPOE.

Harshberger et al, 2011 ¹⁸	Mixed ambulatory and inpatient setting in the USA	A retrospective chart review	CPOE	The mean percentage of identified data points successfully found in the Electronic health records (EHR)/CPOE charts was 93% versus 67% in the paper charts.
Huertas Fernández et al, 2006 ¹⁹	Inpatient setting in Spain	A prospective analysis	CPOE	At least one error was detected in 100% of the manual prescriptions and in 13% of computerized prescriptions. The median of errors per computerized prescription was 0 (range: 0–1), whereas in manual prescriptions the median was 5 (range: 1–12).
Voeffray et al, 2006 ²⁰	850-bed University Hospital, Lausanne, Switzerland	Observational pre and post computational program	CPOE	Before computerization, 141 errors were recorded for 940 prescribed chemotherapy regimens (15%). After the introduction of the CPOE system, 75 errors were recorded for 1505 prescribed chemotherapy regimens (5%). Of these errors, 69 (92%) were recorded in prescriptions that did not use a computerized protocol. A dramatic decrease in the number of errors was noticeable when 50% of the chemotherapy protocols were prescribed through the CPOE system.
George R. Kim, 2006 ²¹	Pediatric Oncology of the Johns Hopkins Children's Center/Sidney (Kimmel Comprehensive Cancer Center)	Pre and post the intervention	CPOE	After CPOE deployment, a significant decrease in the following errors: improper dosing, incorrect dosing calculations, missing cumulative dose calculations, There was no difference in the likelihood of improper dosing on treatment plans and a higher likelihood of not matching medication orders to treatment plans.
Rogers, 2016 ²⁶	academic pediatric hospital 1	pre-post intervention	Education and training of the	Prescribing events decreased from 57% to 25%. Following implementation of age-

	year		prescriber.	specific immunization alerts and mandatory prescriber education, the hospital went 175 days without a vaccine ADEs.
Foster et al, 2013 ²⁷	Paediatric Emergency Department (ED), USA	Pre–post intervention study	Education and training of the prescriber	Significant decrease in dose adjustments and order clarifications.
Thomas et al, 2015 ²⁸	Acute medical unit, in 3 hospitals	Controlled pre–post intervention study	Education and training of the prescriber	Decrease in some specific prescribing error rates, no difference in low- and high-intensity education.
Trivalle et al, 2010 ²⁹	Geriatric center, public 576 elderly patients	Randomized prospective study	Education and training of the prescriber.	Decrease in ADEs in intervention group (22% vs. 36%)
Alagha et al. 2011 ³⁰	139 Paediatric ICU, Egypt	Pre–post intervention study	Education and training of the prescriber.	Significant reduction in prescribing error rate (35.2% vs.78.1%)
Lacomb e et al, 2005 ³¹	University hospital, France	Pre–post intervention study. 75 patients pre-intervention, 52 patients post-intervention	Education and training of the prescriber	Decrease in prescribing errors post intervention vs pre intervention (60.8% vs. 30.8%)
Campin o et al, 2009 ³²	Neonatal ICU, Spain	Pre–post intervention study, 4182 prescriptions pre-intervention, 1512 prescriptions post intervention	Education and training of the prescriber.	Significant reduction in prescribing error rate post intervention vs pre intervention (20.7% vs. 3.0%).
Rajaman i et al, 2011 ³³	General ICU, Australia	Pre–post intervention study, 54 patients pre-intervention, 58 patients post-intervention	Education and training of the prescriber.	There was a highly significant improvement in many error rates - illegible prescriptions reduced from 39.4% to 13.4%; absent or illegible prescriber name from 38.3% to 27.0%; not documenting antibiotic indication from 64.8% to 32.5% .
Martinez-Anton et al, 2012 ³⁴	Pediatric ICU, Spain	Pre–post intervention study, 2228 prescriptions pre-intervention, 1791 prescriptions	Education and training of the prescriber.	Decrease in prescribing errors (21.7% vs. 34.2%).

		post-intervention		
Thomas et al, 2008 ³⁵	ICU, UK pre-intervention,	Pre-post intervention study, 373 prescriptions pre-intervention, 974 and 1022 prescriptions post-intervention	Education and training of the prescriber.	<p>Showed no change in the first month after the intervention.</p> <p>Later reported a significant decrease in prescribing error rates after an education intervention</p>
Burmeser et al, 2008 ³⁶	Pediatric cardiac ICU, USA	Pre-post intervention study 3648 prescriptions pre-intervention, 8929 prescriptions post-intervention	Education and training of the prescriber.	Significant reduction in total prescribing errors (16.8% to 4.8%)
Kozer et al, 2006 ³⁷	899 prescription in the Pediatric emergency care, Canada	Prospective controlled cohort study	Education and training of the prescriber.	No difference in prescribing errors between educated and non-educated residents (12.4% vs.12.7%)
Kaushal et al, 2008 ³⁹	Teaching hospital; pediatric ICU as the study unit and a cardiac ICU for control unit	Pre and post intervention	Pharmacist intervention.	The baseline rates of serious medication errors per 1000 patient days were 29 for the ICU, 8 for the general medical unit, and 7 for the general surgical unit. With unit-based clinical pharmacists, the ICU rate dropped to 6 per 1000 patient days. In the general care units, there was no reduction from baseline in the rates of serious medication errors. A full-time unit-based clinical pharmacist substantially decreased the rate of serious medication errors in a pediatric ICU, but a part-time pharmacist was not as effective in decreasing errors in pediatric general care units.
Klopotoska et al, 2010 ⁴⁰	The Netherland ICU, 28-bed medical and surgical ICU in an	Prospective study compared a baseline period with an intervention period.	Pharmacist intervention.	The ICU hospital pharmacist made a total of 659 recommendations. During the intervention period, the rate of consensus between the ICU hospital pharmacist

	academic hospital			and ICU physicians was 74%. The incidence of prescribing errors during the intervention period was significantly lower than during the baseline period: 62.5 per 1,000 monitored patient-days versus 190.5 per 1,000 monitored patient-days, respectively. Preventable ADEs (patient harm, National Coordinating Council for Medication Error Reporting and Prevention severity categories E and F) were reduced from 4.0 per 1,000 monitored patient-days during the baseline period to 1.0 per 1,000 monitored patient-days during the intervention period. Per monitored patient-day, the intervention itself cost €3, but might have saved €26 to €40 by preventing ADEs.
F. Ranchon et al, 2012 ⁴¹	1200-bed university hospital	cross-sectional observational study	Pharmacist intervention.	The independent risk factors identified should be targeted for preventive measures in order to improve anticancer agent prescriptions and reduce the risk of medication errors.
Lee et al, 2007 ⁴²	United States, 18-bed integrated surgical, medical, and coronary care, ICU in a tertiary care, teaching hospital	Historically controlled study	Pharmacist intervention.	There was no significant difference between the groups for gender and mean age. Of the 267 interventions included in the ICU pharmacist phase, 256 were classified as medication errors compared with 54 of 58 interventions for the control phase. The average number of medication errors per day was significantly higher during the ICU pharmacist phase (4.27 ± 5.2) compared with the control phase (0.92 ± 1.29). The number of medication errors “averted” was higher

				in the ICU pharmacist phase compared with the control phase (212 vs 50). The “averted” medication errors during the ICU pharmacist phase were related to a higher percentage of improved or resolved clinical outcomes compared with the control phase (66/194 [34%] vs 7/46 [15.2%]).
Barakat et al, 2016 ⁴³	500 oncology out-patients in the chemotherapy central clinic, Egypt	cross-sectional observational study	Pharmacist intervention	The identification of risk factors leading to prescribing errors should be targeted for significant decrease in the prescribing errors.
Leape et al, 1999 ⁴⁴	United States, 17-bed medical ICU as the study unit and a 15-bed coronary ICU as the control unit	Pre and post intervention	Pharmacist intervention.	The rate of preventable ordering ADEs decreased by 66% from 10.4 per 1000 patient-days before the intervention to 3.5 after the intervention. In the control unit, the rate was essentially unchanged during the same time periods: 10.9 and 12.4 per 1000 patient-days. The pharmacist made 366 recommendations related to drug ordering, of which 362 (99%) were accepted by physicians.
Chamoun et al, 2016 ⁴⁵	The cardiology and infectious diseases services at a teaching hospital located in Beirut, Lebanon	Retrospective study	Pharmacist intervention	A total of n = 1174 interventions were documented. N = 1091 interventions were classified as MRPs. Interventions were analyzed per 1000 patient days and resulted in 340 medication related problem/1000 patient days. A 72 % reduction in MRP across all ME nodes was seen. The majority of interventions were in the field of cardiology followed by infectious disease related. When interventions per ME

				nodes were analyzed, a high percentage of intervention acceptance was noted across all nodes especially prescribing (68.30 %) monitoring (77.7 %) and in documenting errors (79.36 %).
Haseeb et al, 2016 ⁴⁶	A public emergency hospital in Mecca, Saudi Arabia.	Quasi-experimental study	Pharmacist intervention	Reduction in the incidence of HRAs use from the pre-intervention to post-intervention study period. The five most common abbreviations recorded prior to the interventions were 'IJ for injection' (28.6%), 'SC for subcutaneous' (17.4%), drug name and dose running together (9.7%), 'OD for once daily' (5.8%) and 'D/C for discharge' (4.3%). The incidence of the use of HRAs was highest in discharge prescriptions and dispensing records (72.7%) followed by prescriptions from in-patient wards (47.3%). After the intervention, the overall incidence of HRA was significantly reduced by 52% (ie, 53.6% vs 25.5%). In addition, there was a statistically significant reduction in the incidence of HRAs across all three settings: the pharmacy department (72.7% vs 39.3%), inpatient settings (47.3% vs 23.3%) and emergency wards (40.9% vs 10.7%).

CPOE: Computerized Physician Order Entry, ED: Emergency Department, ICU: Intensive Care Unit, E-prescriptions: Electronic prescriptions, MEs: Medication Errors, EHR: Electronic Health Record, ADEs: Adverse Drug Events, MRPs: Medication Related Problems, HRA: High Risk Abbreviation

CONCLUSION

The integration between the three strategies, computation of physician order entry, education and training of the prescribers as well as the pharmacist intervention in the

prescribing process can lead to enhancement in the prescribing process and minimize the harms reaching the patients. It is obvious in this systematic review that each technique suffers drawbacks and limitations. The coordination and integration between the three interventional strategies tools can overcome each strategy drawbacks when applied separately, and decrease the medication errors occurring in the prescribing stage.

Therefore more studies are required to study the effect of this integration on the prescribing errors and whether this integration could lead to complete prevention of the prescribing error rates in the health care practices.

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