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Do clinical decision support systems for prescribing improve patient safety? a systematic literature review

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ABSTRACT

Clinical decision support systems (CDSS) are developed independently or connected to the electronic health record (EHR) or other computerized systems. The study begins with identification by searching the literature through the Google Scholar, PubMed and ScienceDirect databases. The search results obtained 5,595 articles. Forty-two articles were obtained, which were used further. Most of the research focus is on "CDSS development and evaluation". In terms of impacts, the most common is "reduce prescribing errors". One of the biggest problems reported was the presence of "alert fatigue," which was felt to be disturbing to doctors and pharmacists. CDSS must be supported by a method that is able to indicate the presence of drug-drug interactions (DDI). The use of alerts indicating the presence of a DDI should be interpreted using clinical judgment to determine the risks and benefits of a particular drug for a specific patient. The performance of CDSS is mostly reported to have been able to reduce prescribing errors, which in turn will improve patient safety. However, increased adherence to clinical protocols has not been widely reported. Complaints that are still quite a lot reported are the presence of "alert fatigue", which can interfere with effectiveness.

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1. INTRODUCTION

The clinical decision support system (CDSS) is a computer-based system that supports clinicians in the clinical decision-making process. For this purpose, clinical evidence needs to be provided for any software intended for medical purposes [1]. CDSS is implemented in many hospitals to prevent medication errors and associated harm. Now, doctors are using CDSS more and more in many different areas, such as infection management [2], care for the elderly [3], [4], diabetes mellitus [5], chemotherapy [6], fractures [7], and cardiovascular [8]. However, the rarity of reported evaluations, as well as the high number of studies in the design or pilot phase, suggest that the use of this CDSS to support decision making is considered new and requires further study [9]. When CDSS is used correctly, it makes it possible to combine human intelligence and artificial intelligence, which are both good at doing empirical tasks [10].

The CDSS application for medication is primarily aimed at easing prescribing problems. One of the problems faced in prescribing is checking for drug interactions. Drug-drug interaction (DDI) occurs when one drug enhances or reduces the effect of another drug (i.e., a pharmacodynamic interaction) or affects the absorption, distribution, metabolism, or excretion of another drug (i.e., a pharmacokinetic interaction). These interactions will lead to adverse drug events (ADE) and are associated with a significant burden on the health

care system through increased hospitalizations [11], [12]. Drug interactions are very likely to occur if the patient has comorbidities that require the prescription of several drugs [13]. If the drug-laboratory test interactions (DLTI) is not considered by the physician, incorrect interpretation of the test results can lead to delayed or incorrect diagnosis, unnecessary diagnostic testing, or therapy with possible harm to the patient [14]. Inappropriate prescribing is an important cause of health problems, especially in elderly patients and complex chronic patients. Therefore, continuous monitoring is needed and there is a need for interventions to optimize prescribing, to improve the quality and efficiency of care for the elderly and complex chronic patients [15]. Also, doctors and pharmacists must make sure that no two drugs affect each other in a bad way.

The CDSS for prescribing is one of the innovations aimed at enhancing physician practice performance and patient health outcomes by reducing prescribing errors. Various diseases, including hypertension, cardiovascular disease, gastrointestinal and respiratory tract diseases, diabetes, acquired immunodeficiency syndrome (AIDS), appendicitis, malaria, high blood potassium, kidney disease, and mental illness, have been prescribed using the CDSS [16]. Several prescribing-related CDSS have been developed, such as: i) MedSafety scan [15], which is a hospital-based CDSS to identify patients at risk, and help reduce the risk of harm caused by drugs; ii) PEDeDose [17], supports healthcare professionals caring for pediatric and neonatal patients, enabling them to make informed, evidence-based decisions; iii) PREFASEG [18], automatically generates online alerts for general practitioners when a possible medication-related problems (MRP) is detected; iv) computerized antibiotic stewardship study (COMPASS), a CDSS that has been integrated into an in-house computerized physician order entry system, has been developed to assist physicians in making antimicrobial prescribing decisions [19], [20].

Given the potential for increased CDSS for newer prescriptions, it is necessary to evaluate the effect of implementing CDSS on the relevant impact on patient safety. We therefore intend to review the currently conducted research on CDSS for prescribing. The study focused on discussing: i) the impact of CDSS implementation for prescribing; ii) clinical domains and health services that utilize CDSS; iii) focus on CDSS development; iv) weaknesses of existing CDSS; and v) focus on developing CDSS for future prescribing. The results of the literature review will provide recommendations for further research on CDSS for prescribing.

2. METHOD

This section involves selecting search terms and literature, which is required for the next stage of the mapping phase. It is essential to analyze how some researchers have conducted previous research and their contribution. This literature review will summarize previous research, but it is not a comprehensive analysis of all studies. This section presents the preliminary findings from the systematic literature review conducted to analyze the described domain. It attempts to determine in this regard: i) Impacts and performance indicators relevant to these impacts; ii) Focus of discussion includes: clinical domain, health services implementing CDSS, and focus on developing CDSS; iii) Weaknesses of CDSS for prescribing; and iv) Future trends in developing and implementing CDSS.

This study is a systematic literature review (SLR) which systematically maps several literatures with the aim of collecting and classifying these literatures based on certain criteria [21]. The systematic review process is shown in Figure 1. In this study, it is possible to collect, evaluate, and interpret relevant studies, so that an appropriate evaluation of various research topics can be presented. It is hoped that through this SLR, it can contribute to summarizing the results of research related to the implementation of CDSS for prescribing currently being carried out so that it can be a reference for future research topics. Figure 1 shows that the review process is made up of three steps: planning, implementation, and writing up the results.

2.1. Planning the review

This section describes and discusses a literature review related to CDSS for prescribing. The process begins with ascertaining the need for such a systematic review. The results of this activity are several research questions. These research questions were used as standards for sorting and evaluating all reference articles. There are six research questions as:

- RQ1: What are the impacts of CDSS for prescribing?
- RQ2: What are the clinical domains of DSS for prescribing?
- RQ3: What health services have utilized CDSS for prescribing?
- RQ4: What are the focuses of CDSS development for prescribing?
- RQ5: What are the weaknesses of CDSS for prescribing?
- RQ6: What is the future trend in developing and implementing CDSS?

Furthermore, a review protocol was established, such as the steps for selecting the main study, the way to collect data, the criteria applied (such as inclusion and exclusion criteria), and evaluating the quality of the study.

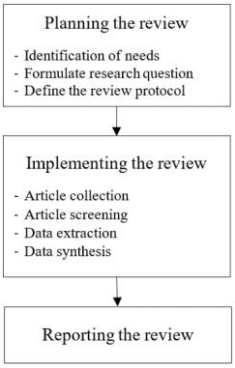

Figure 1. Review process flow diagram

2.2. Implementing the review

Implementing the review was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [12] and is shown in Figure 2. At the identification stage, several articles were searched. Article searches were performed on several scientific publication databases such as Google Scholar, PubMed and ScienceDirect. The keywords used are "clinical decision support system" and "prescribing" in the title, abstract, or author-specified keywords. There were 5,595 articles found, consisting of 5,110 articles searched on the Google Scholar database, 416 articles searched on the PubMed database and 69 articles searched on the ScienceDirect database.

The screening process is carried out on the selected articles. This screening process is carried out for several reasons, such as: i) The existence of duplication of titles; ii) The article does not have a match with the search keyword; or iii) Articles do not use English. The articles obtained were assessed by skimming the full text of their contributions. Furthermore, the screening process was carried out on 309 articles.

2.2.1. Inclusion criteria

The health care burden will increase sharply if the severity of drug consumption at normal doses occurs due to ADE appears [11]. Therefore, there is a need for an alert if there is an interaction between drugs (DDI) in the pharmacodynamic or pharmacokinetic processes. A good CDSS must be able to support the alert. Woosley [15], if the CDSS can assist prescribers, they must have direct access to two general types of data, i) comprehensive information on the drug being prescribed plus all other drugs already available; and ii) information about the patient's medical condition to identify clinical factors that have been shown to influence the patient's response to the drug. In addition, CDSS should be developed by integrating these two data sources and providing alternative prescriptions that can be acted upon without unnecessarily interfering with patient care. McQuade and Campbell [11] and Woosley [15], to evaluate the effectiveness of CDSS for prescribing, the review in this paper included research on: i) Development and evaluation of CDSS that supports prescribing, integration of CDSS with electronic medical records, or integration of CDSS with other computer-based systems used in hospitals; ii) Supported with drug-drug interaction methods to improve CDSS efficacy; iii) The function of alerts in the CDSS application in preventing human errors in drug administration; and iv) The search was carried out on articles from January 2018 to July 2022.

2.2.2. Exclusion criteria

We excluded articles that did not emphasize CDSS and were not focused on prescribing. We also exclude articles that discuss the development of computerized systems for prescribing but are not covered by the CDSS. The CDSS definition for the prescription we use corresponds to that presented in [16]. It does not include articles with insufficient information and literature review articles.

2.2.3. Eligibility and included articles.

The screening results showed that 243 articles did not meet the inclusion criteria, meaning that only 66 articles were eligible for a full-text review. The results of the full-text review show that 24 articles are not worthy of further study because 16 articles do not have sufficient information, and eight articles are literature reviews. Therefore, we only used 42 articles for further analysis.

Furthermore, data extraction is carried out to obtain the data and information needed to build a more detailed research base. Data synthesis is carried out to answer the problem. This is done as a contribution to answering research questions.

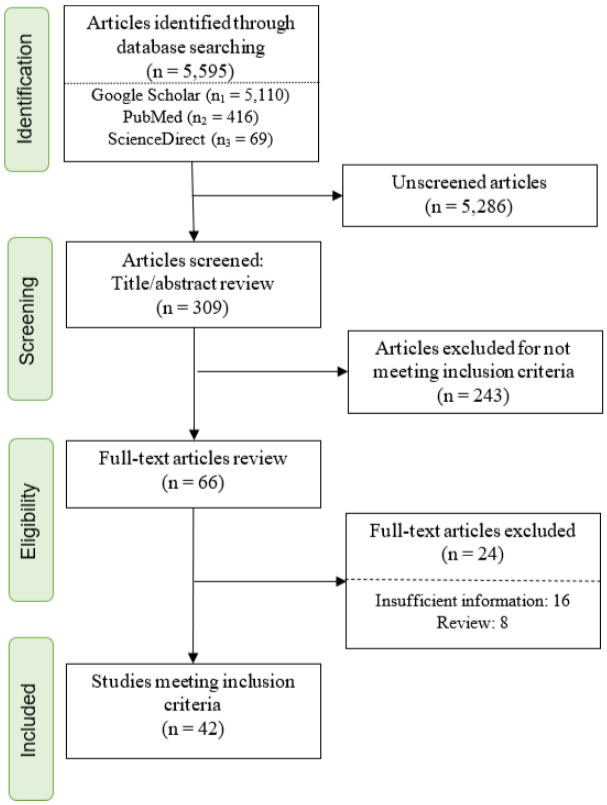

Figure 2. PRISMA flow diagram

2.3. Result of research questions

The summary of the results of reseacrh questions is shown in Table 1. CDSS for prescribing has many impacts on people's lives. The biggest impact is reducing errors in prescribing. In this case, information technology and decision support systems give an important role. Recommendations for alternative solutions as outputs from the decision support system greatly help the effectiveness of the prescribing process.

CDSS for prescribing has been implemented in several domains. Most implementations are for microbials. CDSS provides recommendations for antibiotic selection, priority, dose, duration, route of administration, and alternative antibiotics in the case of allergies. Information on antibiotic side effects and prescription recommendations for specific patient profiles [2].

Table 1. The results of reseacrh questions

No	Research Question	Result
RQ1	What are the impacts of CDSS for prescribing?	CDSS for prescribing has four main impacts, namely: i) reduce prescribing errors, ii) improve compliance with protocols, iii) drug recommendations, and iv) process efficiency.
RQ2	What are the clinical domains of DSS for prescribing?	Tract infection is the most common clinical domain in the application of CDSS for prescribing. On the other hand, CDSS for prescribing has been implemented in several types of medicine, the three largest being in the domains: i) antimicrobials, ii) opioids, and iii) direct oral anticoagulants.
RQ3	What health services have utilized CDSS for prescribing?	CDSS for prescribing has been implemented in several health services, especially in primary care and the Intensive Care Unit.
RQ4	What are the focuses of CDSS development for prescribing?	The development of CDSS for prescribing is mostly done in order to integrate with EHR and represent general practice.
RQ5	What are the weaknesses of CDSS for prescribing?	The main weakness that is often encountered in the application of CDSS for prescribing is the existence of "alert fatigue". Some of the alerts facilitated by this CDSS will actually disrupt the work flow for users.
RQ6	What is the future trend in developing and implementing CDSS?	In the future, the development of CDSS for prescribing will focus more on integration with EHR, reducing fatigue alerts, aligning with professional workflows so that relevant and timely advice can be easily accessed, and evaluating the effect on patient outcomes.

Primary care and the Intensive Care Unit are the two health services that use the most CDSS for prescribing. Both services require CDSS to support doctors during the special drug prescribing process. This is in order to support decision making on whether to prescribe or not. The use of CDSS also helps provide decisions about drug-specific parameters associated with co-treatment protocols [22]. This will reduce errors and improve patient safety.

In several literature reviews, the use of CDSS integrated with EHR resulted in a decrease in antibiotic prescribing. This helps minimize inappropriate antibiotic use, reduces antibiotic resistance, and improves primary care [16]. The patients complied with the reminder messages, but the messages had no effect on the therapy's success rate [23].

The main weakness that is often encountered in the application of CDSS for prescribing is the existence of "alert fatigue". The alert feature is proven to help users in the prescribing process, but excessive use of alerts will result in "alert fatigue". Some of the alerts facilitated by this CDSS will disrupt the workflow for users.

The development of CDSS for prescribing in the future will focus more on integration with EHR, reducing alert fatigue and aligning with professional workflows so that relevant and timely advice can be easily accessed. Several studies recommend conducting additional research to evaluate the impact of CDSS implementation on patient outcomes.

3. RESULTS AND DISCUSSION

We create summaries of research results to help group publications. Information includes the year of publication, clinical domain or development focus, focus of discussion, impacts, performance indicators, and weaknesses. The summary of the results of the literature review is shown in Table 2 in Appendix [2], [5]-[8], [11], [14], [17]-[19], [24]-[55].

3.1. Clinical domain or development focus

CDSS for prescribing is reported to have been developed in various clinical domains, such as: antibiotics and antimicrobials, cardiovascular, internal medicine, respiratory, and mental disorders. There is potential for expansion of the clinical domain in the future. The focus of developing and evaluating CDSS for prescribing has been carried out in various units, such as the intensive care unit (ICU), emergency department (ED), primary care, inpatient care, and hospitals in general.

3.2. Focus of discussion

Most of the discussions in the articles reviewed were about "CDSS development and evaluation", which consisted of 25 articles. Then continued with "electronic prescription alert", which has 15 articles, and "integration of CDSS with EHR or other computer-based applications" with eight articles. Finally, the focus of the discussion on "DDI" is on four articles. Some articles have two focuses, such as [6], [11], [14], [35]-[37], [43], [46], [48], [49]. Although there is not much discussion about DDI, in general, every discussion about alerts is always related to DDI. The discussion related to the integration of CDSS with EHR or other computer-based applications is also a very interesting discussion. CDSS embedded into electronic medical records can ensure safe prescribing of high-risk drugs and potentially save costs associated with potentially preventable side effects [30]. CDSS can improve the quality of patient care by helping doctors review their prescriptions. The integration of CDSS into the EHR can optimize patient safety. This was due to increased compliance with prescriptions and practice guidelines following the adoption of the CDSS [31]. CDSS alerts are becoming a valuable tool for preventing inappropriate high-risk drug prescribing. CDSS can help users identify medication errors. Many irrelevant alerts were reported, causing the alert to be ignored. But a lot of alerts that don't matter can cause "alert fatigue," which makes CDSS less useful [40]. Focus of discussion is shown in Figure 3.

3.3. Impacts

The main goal of CDSS is to improve patient safety. Especially for CDSS, which is built to support prescribing, this increase in patient safety will occur because of reduced prescribing errors. Therefore, "reducing prescribing errors" became the most common impact of the 26 articles we reviewed. The second highest impact was "improved compliance with protocols", which was seven articles. This is in accordance with the definition of CDSS, that the CDSS is built according to health care procedures. The third highest impact is "drug recommendations", namely five articles. The drug recommendation is in accordance with the DSS definition, where the output of the DSS is the solution recommendation. The smallest impact is "process efficiency" which is four articles. When it comes to prescribing, process efficiency is a big part of effectiveness, which can do things like shorten the length of a hospital stay. Impacts and performance indicators are shown in Figure 4.

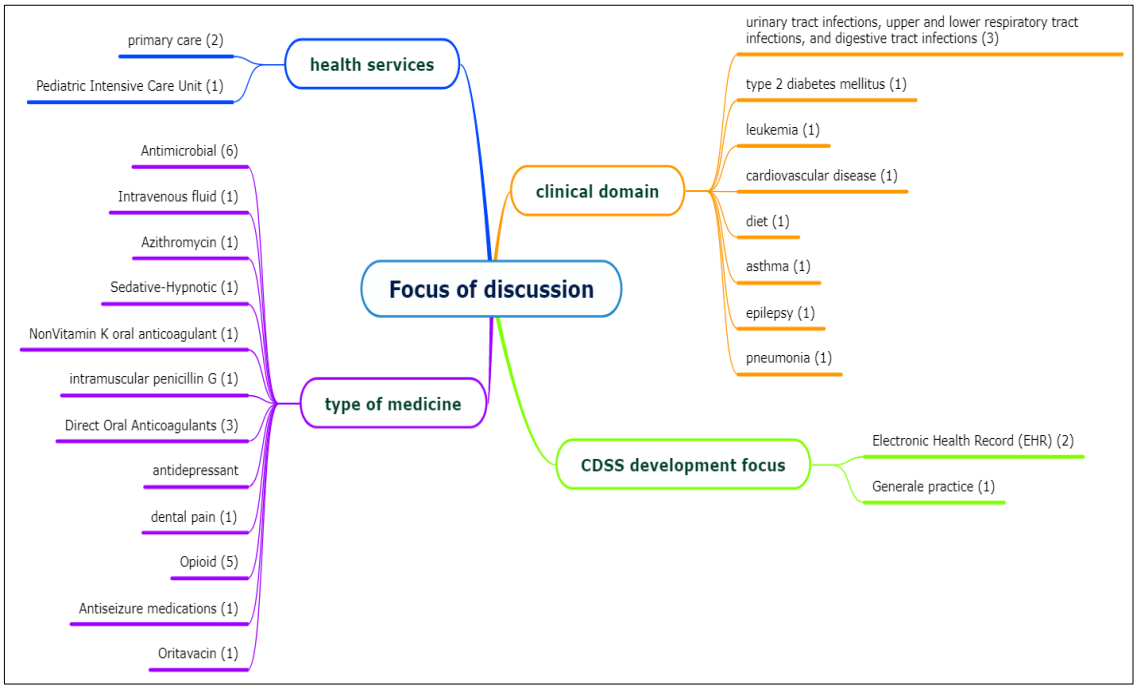

Figure 3. Focus of discussion

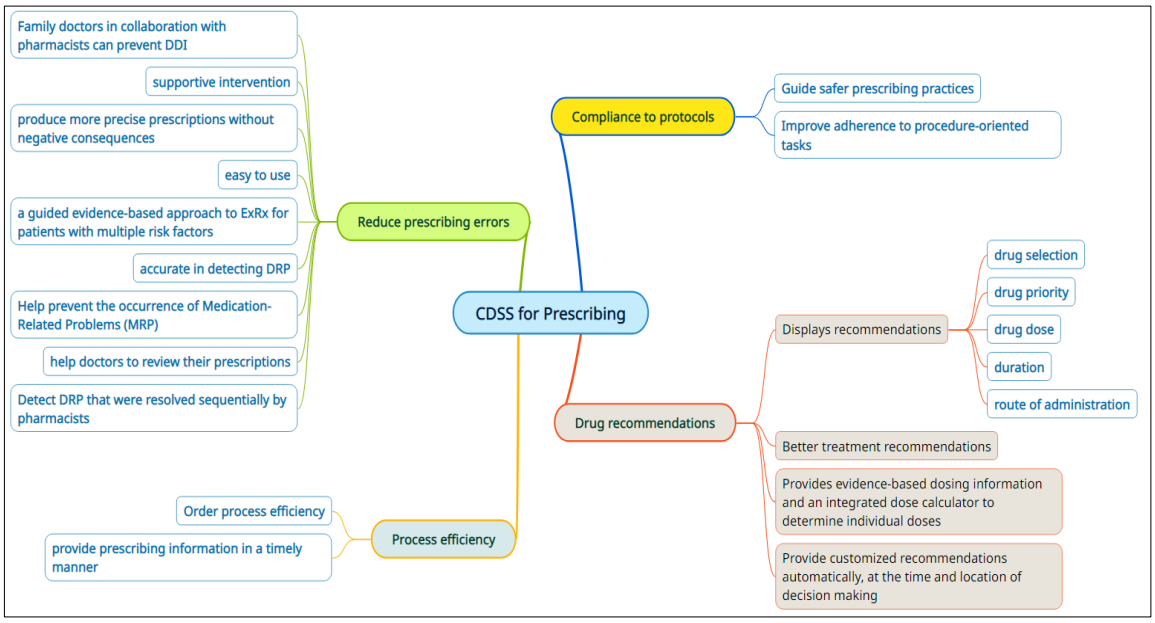

Figure 4. Impacts and performance indicators

3.4. Performance indicators

To produce the expected impact, several indicators or research objectives are found in each article. As each article has a specific purpose, based on the focus of the discussion and the expected impact, the articles can be mapped as shown in Table 3. The most studied area is the discussion of CDSS development & evaluation with impacts reducing prescribing errors, namely 16 articles. The performance indicators used are helping prevent the occurrence of MRP, assisting users in recognizing medication errors, reducing accidental prescription doses, and helping doctors to review their prescriptions. The second is a discussion of electronic prescription alerts with the impacts of reducing prescribing errors, namely 14 articles. The performance indicators used are reduction in the economic burden, promoting patient safety, and improving the safety of

patients' care. The discussion on DDI is only mapped with the impact of reducing prescribing errors. The discussion on electronic prescription alerts is only mapped to two impacts, namely reducing prescribing errors and improving compliance with protocols.

Table 3. Mapping of "focus of discussion" with "impacts"

Focus of discussion	Impacts			
	Reduce prescribing errors	Improve compliance with protocols	Drug recommendations	Process efficiency
CDSS development and evaluation	[6], [7], [18], [24], [26], [29], [30], [35], [39], [43]-[46], [48], [49], [55]	[31], [42]	[2], [40],[41], [53]	[5], [8], [19]
CDSS and EHR (or other system) integration	[34], [50], [52]	[17], [47], [51]	[33]	[25]
Electronic prescription alert	[6], [11], [14], [18], [28], [32], [35], [36], [37], [38], [43], [46], [48], [49]	[27], [54]	-	-
DDI	[11], [14], [36], [37]	-	-	-

3.5. Weaknesses

A total of eight articles reported the weaknesses in the implementation of CDSS. The eight weaknesses are: i) incomplete information about drug side effects, prescribing recommendations for specific patient profiles, and adaptation to local epidemiology [2]; ii) the increase in prescribing time using CDSS is overestimated by end users [19]; iii) different prescribers' perceptions of the relevance of alerts [24]; iv) great variation in response to inpatient and outpatient alerts, as well as multiple alerts fatigue [27]; v) time consuming to get data and workflow interruption [44]; vi) the "alert fatigue" caused by a large number of irrelevant alerts reduces the effectiveness of CDSS [49]; vii) has no impact on compliance with appropriate usage guidelines [50]; and viii) the effect on clinical impact remains unclear [53].

Several factors must be considered for the CDSS for prescribing to achieve good performance and be accepted by stakeholders. First, it is necessary to integrate the CDSS with EHR or other systems so that the decision-making process carried out by stakeholders is based on informed evidence. In particular, the integration of CDSS with other systems can help doctors choose the right drug at the right dose and remind doctors when prescribing the drug, which will ultimately result in safer drug prescribing [56]. The integration of CDSS into computerized physician order entry systems at home has been shown to assist physicians in making prescribing decisions [19], [40]. Integrated CDSS with EHR, combined with supportive interventions, results in more precise antibiotic prescribing, without adverse effects on residents [52]. The implementation of the appropriate use guidelines with CDS integration into the CPOE system reduced the overall use of medicine but had no effect on adherence to the guidelines [50].

Second, the CDSS needs to be supported by good DDI. To increase the performance of DDI software, the integration of DDI-specific screening intervals and patient-specific variables is necessary [37]. "Alert" is an important component as a marker of interactions between drugs. Well-designed electronic prescribing alerts and providing prescribing relevant information are likely to result in benefits for physicians and patients as well as a reduced economic burden. Clinicians actively seek to reduce risk when responding to high-severity alerts [57]. Excessive alerts are less likely to distract doctors than administering CDSS. Alerts that are designed with a good user interface will greatly enhance the effectiveness of alerts. These user interface components, such as the efficient and consistent use of color and language, a minimalist approach to information layout and controls, the use of font attributes to convey hierarchy and visual prominence of important data over supporting information, the inclusion of relevant patient data in the context of alerts and enabling clinicians to respond with a click or two [58]. Regarding alert fatigue, several efforts are needed to reduce it, such as: i) equalizing the perception of prescribers regarding the relevance of alerts; ii) the alerts generated by the CDSS should be interpreted using clinical judgment to determine the risks and benefits of a particular drug on a specific patient basis; iii) to avoid over alerting health professionals and to maintain good efficiency, the alerts have to be analyzed by a pharmacist [54]; and involving clinical pharmacists in the development and management of CDSS can reduce the number of irrelevant alerts given to clinicians.

The successful implementation of CDSS is due to several factors such as user-friendliness, adherence to clinical guidelines, patient-physician collaboration, integration of electronic health records, pharmacy systems, consideration of physicians' views in assessing the importance of CDSS alerts, and real-time alerts in prescribing [16]. The success of CDSS is not only judged by the level of user acceptance and increased prescribing performance, but also must increase compliance with the correct prescribing guidelines. Patient safety can be improved with CDSS developed with user-centric design principles. Engagement between stakeholders is considered essential for interventions aimed at ensuring prescribers continue to utilize their functions [24]. Similarly, the involvement of end users in clinical decision support designs can facilitate

adoption [25]. CDSS can encourage and standardize prescribing, changing practices more effectively. The perception that CDSS improves patient safety and efficiency encourages the use of CDSS [59].

CDSS in electronic prescribing systems is proven to improve the quality, safety, efficiency, and cost-effectiveness of medication. However, at present, the potential benefits have not been fully realized. There are three important influencing factors [60]: i) improvement in system performance, including the intervention settings and CDSS knowledge base, supporting database elements, operational features to improve system usability, and management and governance structures; ii) uniform standards, vocabulary, structure, and centralized knowledge service that can reduce rework by vendors and service providers, increase the distribution of well-constructed CDSS interventions, promote research that is generally applicable as a decision-making method, and accelerate the transfer of new medical knowledge from research to practice; and iii) appropriate financial and legal inducements to promote adoption. Therefore, further research is needed to address these three factors.

4. CONCLUSION

Based on the literature review that has been carried out, it can be concluded that the performance of the CDSS for prescribing has largely been able to reduce prescribing errors, which in turn will increase patient safety. A small proportion reported increased adherence to clinical protocols. Complaints that are still quite a lot reported are the presence of "alert fatigue", which can interfere with the effectiveness of the CDSS. The integration of CDSS with EHR or other computerized systems used by health care institutions will greatly assist doctors in making clinical decisions. In the future, it is still necessary to review the strategy to reduce "alert fatigue" so that the developed CDSS is more acceptable to stakeholders, especially doctors and pharmacists.

APPENDIX

Table 2. Summary of review results

No	Ref	Year	Clinical domain or development focus	Focus of discussion	Impacts	Performance indicators	Weaknesses
1	Durand *et al.* [2]	2022	Antibiotics in urinary tract infections, upper and lower respiratory tract infections, and digestive tract infections	CDSS development and evaluation	Drug recommendations	Displays recommendations for antibiotic selection, priority, dose, duration, route of administration, and alternative antibiotics in case of allergy.	Information about side effects of antibiotics, prescribing recommendations for specific patient profiles, and adaptation to local epidemiology is often missing or incomplete.
2	Larsen *et al.* [5]	2022	Type 2 diabetes mellitus	CDSS development and evaluation	Process efficiency	Order process efficiency	-
3	Moghaddasi *et al.* [6]	2022	Chemotherapy of Children with Acute Lymphoblastic Leukemia	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Improve adherence to chemotherapy protocols and reduce chemotherapy prescribing errors which can improve patient safety.	-
4	Pescatello *et al.* [8]	2021	Patients With Multiple Cardiovascular Disease Risk Factors	CDSS development and evaluation	Process efficiency	It has proven to be an easy-to-use, guided and time-efficient evidence-based approach to ExRx for patients with multiple CVD risk factors.	-

Table 2. Summary of review results (*continue*)

No	Ref	Year	Clinical domain or development focus	Focus of discussion	Impacts	Performance indicators	Weaknesses
5	McQuade and Campbell [11]	2022	Electronic Health Record (EHR)	DDI, electronic prescription alert	Reduce prescribing errors	Family doctors in collaboration with pharmacists can prevent DDI, and optimize drug safety	-
6	Tukukino *et al.* [14]	2022	Drug interaction alerts in older primary care patients	DDI, Electronic prescription alert	Reduce prescribing errors	Relevant from a medical perspective	-
7	Ranzani *et al.* [19]	2022	Antimicrobial	CDSS development and evaluation	Process efficiency	-	The increase in prescribing time using CDSS is overestimated by end users.
8	Jeffries *et al.* [24]	2021	Generale practice	CDSS development and evaluation	Reduce prescribing errors	Improve medication safety and provide prescribing information in a timely manner.	Different prescribers' perceptions of the relevance of alerts.
9	Spiegel *et al.* [25]	2021	Intravenous fluid	CDSS and EHR (or other system) integration	Process efficiency	Powerful and continuous improvement in balanced fluid prescription	-
10	May *et al.* [26]	2021	Azithromycin Prescribing in Primary Care Clinics	CDSS development and evaluation	Reduce prescribing errors	Reduction of inappropriate azithromycin prescribing	-
11	Joglekar *et al.* [27]	2021	Sedative-Hypnotic Prescribing in Older Adults	Electronic prescription alert	Improve compliance with protocols	-	Great variation in response to inpatient and outpatient alerts, as well as multiple alerts fatigue
12	Khalil *et al.* [28]	2021	NonVitamin K oral anticoagulant	Electronic prescription alert	Reduce prescribing errors	Electronic prescribing alerts are beneficial for doctors and patients, as well as a reduction in the economic burden.	-
13	Pallotta and Wesolowski [29]	2021	intramuscular penicillin G	CDSS development and evaluation	Reduce prescribing errors	Reduce medical errors	-
14	Ahuja *et al.* [30]	2021	Direct Oral Anticoagulants	CDSS development and evaluation	Reduce prescribing errors	Prescription safety	-
15	VanDaele *et al.* [31]	2021	high-risk antidepressant	CDSS development and evaluation	Improve compliance with protocols	Improved compliance with prescriptions and guidelines	-
16	Smith *et al.* [32]	2022	high-risk medications	Electronic prescription alert	Reduce prescribing errors	Promote patient safety	-
17	Rigert *et al.* [17]	2022	Dental pain	CDSS and EHR (or other system) integration	Improve compliance with protocols	Guide safer prescribing practices	-
18	Meid *et al.* [33]	2021	Direct Oral Anticoagulants	CDSS and EHR (or other system) integration	Drug recommendations	Better treatment recommendations	-
19	Nabovati *et al.* [34]	2021	Acute respiratory infection	CDSS and EHR (or other system) integration	Drug recommendations	Potential to increase antibiotic prescription	-

Table 2. Summary of review results (*continue*)

No	Ref	Year	Clinical domain or development focus	Focus of discussion	Impacts	Performance indicators	Weaknesses
20	Bestha *et al*. [35]	2022	Opioid	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Improve patient safety	-
21	Levivien *et al.* [36]	2022	Prescriptions with low risk of DRP (Drug Related Problem)	DDI, electronic prescription alert	Reduce prescribing errors	CDSS has been shown to be accurate in detecting DRP, and considerably improves patient safety.	-
22	Sijpe *et al*. [37]	2022	DDI	DDI, electronic prescription alert	Reduce prescribing errors	Considerably improves the safety of patients' care.	-
23	Cherney *et al.* [38]	2021	Recurrent asthma	Electronic prescription alert	Reduce prescribing errors	Electronic alerts suggesting prescribing Inhaled Corticosteroids (ICS) in the ED for patients with repeated asthma visits are effective, even without financial incentives.	-
24	Hadady *et al*. [39]	2022	Antiseizure medications (ASMs) for epilepsi	CDSS development and evaluation	Reduce prescribing errors	Provide valuable assistance to health care professionals prescribing medication for individuals with epilepsy.	-
25	Higi *et al*. [40]	2022	Paediatrics	CDSS development and evaluation	Drug recommendations	Provides evidence-based dosing information and an integrated dose calculator to determine individual doses.	-
26	Pons-Mesquid, *et al.* [18]	2021	Primary care	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Help prevent the occurrence of Medication-Related Problems (MRP).	-
27	Rawson *et al*. [41]	2021	Antimicrobial	CDSS development and evaluation	Drug recommendations	Provide recommendations that are more precise than current clinical practice.	-
28	Elchynski *et al.* [42]	2021	PGx-CDS	CDSS development and evaluation	Improve compliance with protocols	PGx-CDS is well received by prescribing healthcare providers	-
29	Bittmann *et al.* [43]	2021	14 drugs and 36 drug combinations	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Assisting users in recognizing medication errors, particularly interruptions with a high risk of ADE	-
30	Calcaterra *et al.* [44]	2021	Opioid and Benzodiazepine	CDSS development and evaluation	Reduce prescribing errors	Prescription Drug Monitoring Programs (PDMP) reduces deaths caused by opioids.	Time consuming to get data and workflow interruption.
31	Hashemi *et al.* [45]	2022	PICU (Paediatric Intensive Care Unit)	CDSS development and evaluation	Reduce prescribing errors	Effectively reduces prescription errors, can check & suggest normal doses and dosage limits, and is able to significantly reduce accidental prescription dose deviations.	-

Table 2. Summary of review results (*continue*)

No	Ref	Year	Clinical domain or development focus	Focus of discussion	Impacts	Performance indicators	Weaknesses
32	Rozenblum *et al.* [46]	2020	Electronics Medical Record	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Identify clinically valid medication error alerts, and potential cost savings associated with potentially preventable side effects.	-
33	Wai *et al*. [47]	2019	High-dose parenteral thiamine in hospitalized patients with Alcohol Use Disorder (AUD)	CDSS and EHR (or other system) integration	Improve compliance with protocols	Be an effective method for specialized services to improve proper care practices without additional education or training for providers.	-
34	Siegel *et al*. [48]	2021	Ketogenic diet	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Sustained reduction in carbohydrate-containing drug orders for hospitalized patients on the ketogenic diet without increased alert burden.	-
35	Cuvelier *et al*. [49]	2021	Pharmaceutical interventions	CDSS development and evaluation, electronic prescription alert	Reduce prescribing errors	Improve the quality of patient care by helping doctors to review their prescriptions.	The "alert fatigue" caused by a large number of irrelevant alerts can decrease the effectiveness of a CDSS.
36	Treu *et al*. [50]	2021	Oritavancin	CDSS and EHR (or other system) integration	Reduce prescribing errors	Lower overall use of oritavancin	Has no impact on compliance with appropriate usage guidelines.
37	Price-Haywood *et al.* [51[	2020	Prescribing Opioids for Chronic Noncancer Pain	CDSS and EHR (or other system) integration	Improve compliance with protocols	Improve adherence to procedure-oriented tasks	-
38	Rutten *et al*. [52]	2022	Urinary tract infection	CDSS and EHR (or other system) integration	Reduce prescribing errors	Supportive intervention, resulting in more appropriate antibiotic prescribing without negative consequences for residents.	-
39	Wohler *et al*. [7]	2021	Opioid prescribing risk factors in nonoperative ankle fractures	CDSS development and evaluation	Reduce prescribing errors	Identifying an area of improvement for prescribers	-
40	Sennesael *et al.* [53]	2020	Oral anticoagulants	CDSS development and evaluation	Drug recommendations	Provide customized recommendations automatically, at the time and location of decision making	The effect on clinical outcome remains unclear.
41	Potier *et al*. [54]	2022	DRP (Drug Related Problems)	Electronic prescription alert	Improve compliance with protocols	Detect DRP that were resolved sequentially by pharmacists.	-
42	Mostaghim *et al*. [55]	2019	Antibiotics in patients with pneumonia	CDSS development and evaluation	Reduce prescribing errors	The use of CDSS did not reduce the use of antibiotics according to the presumptive diagnosis of Community-Acquired Pneumonia (CAP).	-

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