A Narrative Review of Clinical Decision Support for Inpatient Clinical Pharmacists

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Abstract

Objective Increasingly, pharmacists provide team-based care that impacts patient care; however, the extent of recent clinical decision support (CDS), targeted to support the evolving roles of pharmacists, is unknown. Our objective was to evaluate the literature to understand the impact of clinical pharmacists using CDS.

Methods We searched MEDLINE, EMBASE, and Cochrane Central for randomized controlled trials, nonrandomized trials, and quasi-experimental studies which evaluated CDS tools that were developed for inpatient pharmacists as a target user. The primary outcome of our analysis was the impact of CDS on patient safety, quality use of medication, and quality of care. Outcomes were scored as positive, negative, or neutral. The secondary outcome was the proportion of CDS developed for tasks other than medication order verification. Study quality was assessed using the Newcastle–Ottawa Scale.

Results Of 4,365 potentially relevant articles, 15 were included. Five studies were randomized controlled trials. All included studies were rated as good quality. Of the studies evaluating inpatient pharmacists using a CDS tool, four showed significantly improved quality use of medications, four showed significantly improved patient safety, and three showed significantly improved quality of care. Six studies (40%) supported expanded roles of clinical pharmacists.

Conclusion These results suggest that CDS can support clinical inpatient pharmacists in preventing medication errors and optimizing pharmacotherapy. Moreover, an increasing number of CDS tools have been developed for pharmacists' roles outside of order verification, whereby further supporting and establishing pharmacists as leaders in safe and effective pharmacotherapy.

Keywords
- clinical decision support
- pharmacy information systems
- inpatient care
- pharmacy
- clinical informatics
- pharmacist

Background and Significance

Pharmacists' roles have expanded from traditional medication verification and dispensing to team-based patient care.[1,2] Since the early 1970s, pharmacists have been tangentially involved with inpatient care through pharmacokinetic consultations. More recently, pharmacists are assuming providers' roles with collaborative practice agreements, which in some cases allow them to manage chronic health care conditions, such as diabetes and cardiovascular conditions.[1] Clinical pharmacists' roles are becoming more specialized through pharmacy residency training programs and specialty certification, and they are recognized as crucial members of the multidisciplinary health

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care team.[3] As with providers, clinical pharmacists can be supported by health information technology, which has been considered a major factor in preventing medication errors and patient harm.[2]

Electronic health record (EHR) adoption and clinical decision support (CDS) implementation have also expanded in recent years.[4] As of 2017, 94% of U.S. hospitals used an EHR system.[4] CDS has been characterized as a health information technology that provides patient-specific information that is intelligently filtered and presented at appropriate times for decision making.[5–7] CDS can be developed and refined through clinician observations, suggestions, and preferences.[8–10] Some examples of CDS include passively providing clinicians with helpful information without interrupting their workflow or process, such as order facilitators (e.g., order sets and default settings), relevant information displays (e.g., info-buttons and links to additional resources), and even in-line displays of information (e.g., allergy or dose alerts).[11] CDS also includes active or interruptive alerting, such as hard-stop alerts and reminders. Unfortunately, even with more EHRs and CDS, deaths from medication errors still occur at an alarming rate.[12]

Pharmacists play a crucial role in identifying and preventing medication errors and CDS tools can help improve pharmacists' proficiency. A study found that 64% of prescribing errors could be prevented with pharmacists and CDS. The authors concluded that pharmacists' involvement is crucial for achieving maximum medication safety.[1] Moreover, systematic reviews have examined the impact of CDS on a broad range of pharmacy services, demonstrating the benefit of combining pharmacists and CDS.[13,14] Pharmacists not only use the EHR and CDS, but they also contribute to their design and implementation.[15] By including pharmacists in CDS design and implementation, the performance and reliability can be increased.[16]

With pharmacists assuming more clinical roles and more CDS tools being developed to support those roles, there is a need to examine the impact of CDS on clinical pharmacy practice. In this study we present a review of the literature regarding the impact of CDS and how it has evolved with clinical pharmacists. We anticipated that inpatient pharmacists using CDS will improve outcomes and that recent CDS supports pharmacists' roles beyond medication verification and dispensing (►Fig. 1).

Methods

The study protocol was registered in PROSPERO (CRD420150 16952).[17] We conducted a review of published studies to evaluate the impact of the CDS tools targeted at pharmacists in the inpatient setting. We aligned this review with the PRISMA guidelines and methods from the Cochrane Handbook.[18]

Search Strategy and Study Eligibility

Working with a medical librarian, we identified cohort studies, observational studies, randomized control trials, and quasi-experimental studies, by searching MEDLINE, EMBASE, and Cochrane Central between January 2009 and October 2020. The search strategy was developed for MEDLINE using PubMed and iteratively refined to capture preidentified studies (►Table 1). We combined keywords, headings, and other search strategies to develop search terms. Once the search strategy was refined with PubMed, we adapted to the other databases. Study inclusion criteria are provided in ►Table 2. Studies were excluded if there was no computerized system involved; the computerized system was not designed with pharmacists as the intended recipients; or the study was not in English. We used Covidence (Melbourne, Australia) to screen studies.[19] Two reviewers

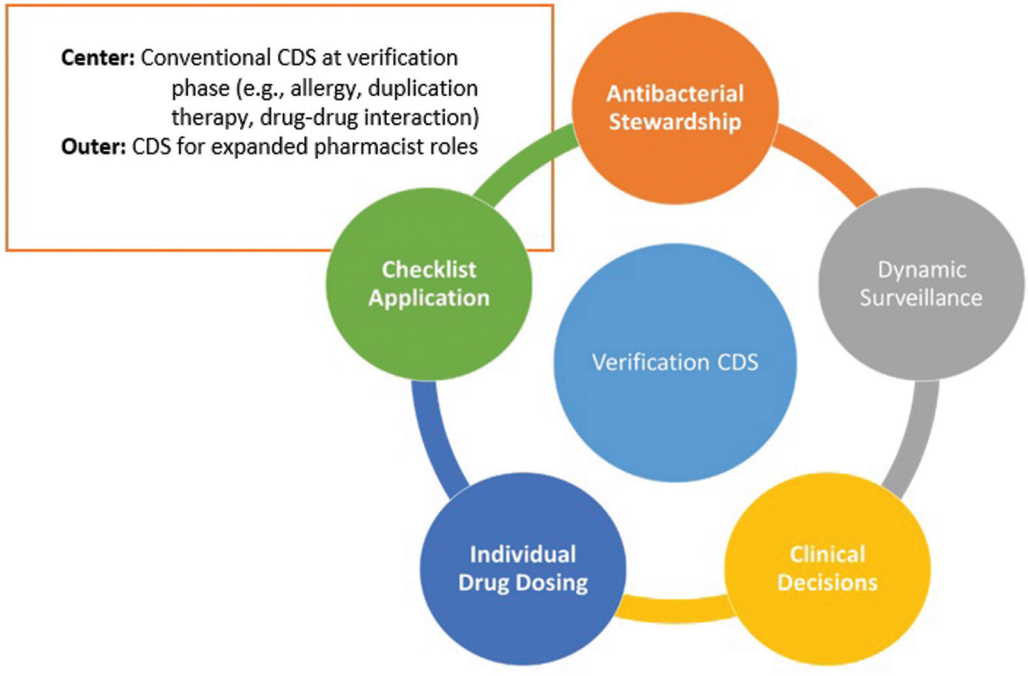

Fig. 1 Expanding roles of pharmacists.

Table 1 Pharmacy CDS review: PubMed search strategy

Search terms were translated to EMBASE and Cochrane Central database
(
"Medical Order Entry Systems/utilization"[Mesh] OR
"Online Systems"[Mesh] OR
"User-Computer Interface"[Mesh] OR
"Medical Informatics Computing"[Mesh] OR
"Medical Informatics"[Mesh] OR
"Medical Informatics Applications"[Mesh] OR
"Medical Order Entry Systems"[Mesh] OR
"Pharmacist intervention" [All Fields] OR
"Drug Prescriptions"[Mesh] OR
"Electronic Prescribing"[Mesh] OR
"Medication Systems"[Mesh] OR
"Drug Therapy, Computer-Assisted"[Mesh] OR
"Medication Errors"[Mesh] OR
"Computerized p*" [All Fields] OR
"Electronic p*" [All Fields] OR
"CPOE"[All Fields] OR
"Computerized order entry"[All Fields] OR
"Electronic order entry"[All Fields] OR
"Medication Reconciliation"[Mesh] OR
"Pharmacists/organization and administration"[Mesh] OR
"Drug Information Services"[Mesh] OR
"Drug Interactions"[Mesh] OR
"Guideline Adherence"[Mesh] OR
"Practice Patterns, Pharmacists'" [All Fields] OR
"Medication review" [All Fields] OR
"Medication admin*" [All Fields] OR
"Clinical Pharmacy Information Systems"[Mesh] OR
"Pharmacy Service, Hospital"[Mesh] OR
"Pharmaceutical Services"[Mesh] OR
"antimicrobial steward*" [tiab] OR
"antibiotic steward*" [tiab] OR
"pharmacokinetic service"[tiab]
OR Pharmacotherapy [all fields]
)
AND
(
"Decision Support Systems, Clinical"[Mesh] OR
"Decision Making, Computer-Assisted"[Mesh] OR
"Decision support" [All Fields] OR
"electronic alerts"[All Fields] OR
"computer alerts"[All Fields] OR
"computerized alerts"[All Fields] OR
CDS*[All Fields] OR
"Reminder Systems"[Mesh] OR
Remind*[All Fields] OR
Alert*[All Fields] OR
Prompt*[All Fields] OR
Notif*[All Fields] OR
Interrupt*[All Fields]
OR electronic display [all fields]
)
AND
(
"Pharmacists"[Mesh] OR
pharmacist*[All Fields]
)
AND
(
"2009/01/01"[PDAT]: "2018/12/01"[PDAT]
)

Abbreviation: CDS, clinical decision support.

independently screened title/abstracts and full texts and a third reviewer resolved any disputes.

Quality Assessment

Since the included studies had different designs and outcomes, we used the Newcastle–Ottawa Scale to assess study quality.[20] Two reviewers independently assessed each included study. Additionally, it was noted whether the study conducted proper statistical analyses and whether the authors had mentioned possible contamination of the study groups.

Reporting and Analysis

Outcomes were grouped into three main categories: quality use of medication, drug and pharmacotherapy safety, and quality of care. Quality use of medication was defined as the accuracy of medication use and proper management of disease, such as appropriate dosing of medications. Drug and pharmacotherapy safety was defined as the safety of medication use, which was demonstrated by avoiding adverse events or death. Quality of care was defined as patient outcomes, which included parameters such as patient satisfaction and hospital length of stay.

The impact of the CDS intervention was characterized by assigning labels for each study result: "+" study favored the CDS intervention; "−" study favored the control group; "0" was no difference between the intervention and control groups; and "NS" the study did not conduct any statistical analysis or that there was no statistically significant data reported for the specified outcome.

We reported outcome data on whether studies demonstrated at least one positive outcome (i.e., general trend in favor of CDS for a prescribing, clinical, or patient outcome) and statistically significant improvements in favor of CDS on greater than or equal to 50% of outcomes. We chose to report trends as well as significant results given the likelihood that some studies were underpowered to detect statistically significant differences in outcomes. The outcome data are summarized in a narrative manner instead of a meta-analysis due to the heterogeneity of the study methodologies, comparison groups, intervention targets, and results.

Results

The search resulted in 4,365 articles. Based on title/abstract screening, 90 articles were selected for full-text review. Fifteen studies met the inclusion criteria (►**Fig. 2**). Most excluded studies were primarily focused on CDS used by providers and implementations outside the inpatient settings. Key features of the included studies are shown in ►**Table 3**.[20–34]

Study Quality

Of the 15 included studies, 5 were randomized controlled trials,[27,30,31,33,34] 6 were quasi-experimental,[22,25,28,29,32,35] 2 were observational,[23,26] and 2 were cohort studies.[21,24] All of the studies had a control group and all 15 studies were deemed as good quality using the Newcastle–Ottawa Scale.

Table 2 Study inclusion criteria

P: participant/population	Studies listing pharmacists among recipients of the CDS system in the inpatient setting.
I: intervention	The described CDS system had to provide patient-specific information and/or generate information in an electronic format.
C: comparator/control	A comparison of performance of the CDS to routine care or other CDS or computerized prescriber order entry (CPOE) systems.
O: outcome	The primary outcome of the study had to include patient care, clinician effect, or processes of care. The studies also had to report measured or quantifiable outcomes, such as cost, patient outcomes, adverse drug events, clinical interventions, etc.

Abbreviation: CDS, clinical decision support.

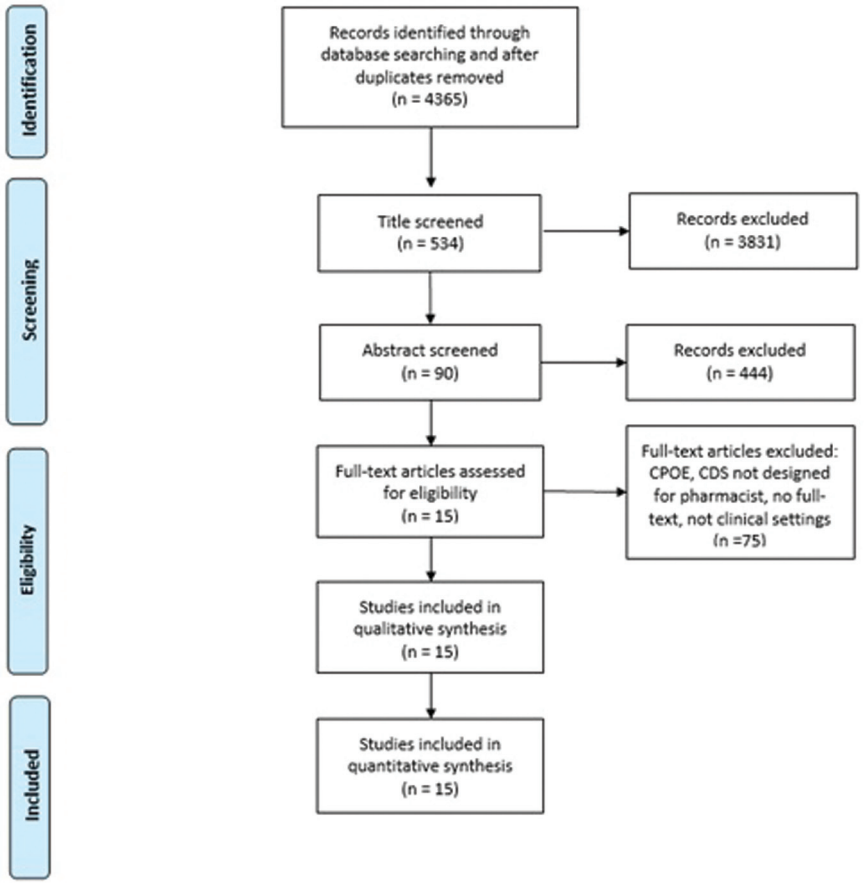

Fig. 2 PRISMA diagram.

Study Characteristics

Study outcomes were analyzed in three main groups, including quality use of medication, drug and pharmacotherapy safety, and quality of care (►Table 3). Four studies examined the quality use of medications,[23,27,31,35] seven studies looked at drug and pharmacotherapy safety,[22,24,25,29,30,33,34] and five studies evaluated the quality of care.[21,25,26,28,32] One study qualified as both drug and pharmacotherapy safety and quality of care. Pharmacists interacted directly with patients in one study through medication reconciliation[32] and all other CDS systems did not have pharmacist–patient interactions: most of the data were based on measured laboratory results and recorded patient information by nurses and laboratory technicians.

Pharmacists were warned of potential errors through CDS alerting in 11 of the studies. For example, two studies had alerts that interrupted a pharmacist's workflow when a patient had an abnormal serum creatinine.[30,34] These alerts were designed to prevent medication-caused acute kidney injury and therefore required the pharmacist's immediate attention. None of the included studies discussed alert fatigue or workflow disruption.

Other CDS interventions provided support without interrupting pharmacists' workflow. For example, two studies examined a CDS system that calculated the dose of antibiotics for the pharmacist.[23,35] Another study evaluated a CDS system that helped identify medication reconciliation errors.[32] Finally, one study used CDS to examine cost–benefit analysis of medication use.[27]

Table 3 Key features of the included studies

Study	Type	Quality	Participants (*n*)	Intervention	Control	Outcome measures	Study results	Statistically significant
Aziz et al	Prospective cohort study	Good	2,649 and 3,064 interventions in phase 1 (preintervention) and 2 (CDS intervention)	Electronic prompt that asks pharmacist to re-evaluate his rejected pharmacotherapy intervention	Preintervention and multidisciplinary team	Quality of care: re-evaluated a pharmacist-rejected intervention to determine it is accurate	(+) Decreased number of inappropriate rejections by 56%.	NS
Boussadi et al	Quasi-experimental	Good	5,006 total alerts during the study time period. 404 decision difference between CDS alert and pharmacist	Electronic alert checks dosing error of drug orders	Pharmacist checks	Safety: dose check	(+) 50% overdoses detected by CDS while 14% detected by pharmacist.	NS
Claus et al	Prospective observational study	Good	87 patients on selected antibacterial drugs that require creatinine for dose calculation	Electronic antimicrobial dose alert provides dosing advice based on 24-hour creatinine clearance	Pharmacist review	QUM: "antimicrobial dose based on SCr" (ADC) accuracy alert and pharmacist workload	(+) 78.5% correct dosing prescription. 13.4% overdosed, and 8.1% underdosed. Pharmacist time per patient reduced by 76.5%.	NS
Cornu et al	Prospective cohort study	Good	50 patients followed by clinical pharmacists	CDS DDI alert system	Pharmacist check	Safety: compare rate of DDI and rate of acceptance between CDS DDI alert and pharmacist verifications	(−) 240: 6 DDIs by pharmacist: CDS (−) 81%: 0 accepted advise by physician	Statistically significant
Cox et al	RCT	Good	Patient started on tobramycin or amikacin during study period (97 amikacin patients and 119 tobramycin patients)	CDS dosing selection for patient initiating on tobramycin or amikacin	Preintervention	QUM: pharmacist calculated amikacin/tobramycin dose alert (within ±10% of the study reference standard)	(+) 40% dosing accuracy in the pre-CDS arm to 80% in the post-CDS arm	Statistically significant
Diaz et al	Quasi-experimental	Good	171 patients >18 years of age admitted to medical and surgical services with an eGFR < 60 mL/min	CDS with drug-allergy checking, formulary decision support, and DDI checking	Preintervention	Safety, quality of care: evaluate the efficacy of CDS on the frequency of appropriate prescriptions.	(+) 65% pre-CDS, 86% after intervention. Correct prescription based on renal function	Statistically significant
Eppenga et al	Prospective observational study	Good	Patient admitted in 5 randomly chosen consecutive days. 150 alerts generated by basic CDS and 384 alerts generated by advanced CDS	Advanced medication alert CDS with multiple functionality	Basic medication alert CDS	Quality of care: compare the performance of two medication alert CDSs	(+) Advanced CDS has higher positive predicted value (17%) compared with basic CDS (5.8%).	Statistically significant
Study	Type	Study quality	Participants (*n*)	Intervention (types of CDSS)	Control	Outcome measures	Study results	Statistically significant
Gallagher et al	RCT and cost-effective analysis	Good	361 patients admitted to the hospital within the study timeline were randomized into each group	CDS integrated with STOPP/START criteria for elderly patients	Preintervention	QUM: cost-effectiveness analysis of SPRM/CDSS for elderly patients	(+) CDS group was associated with a decrease of €807 in mean health care cost (+) Decrease in the mean number of ADR events per patient	NS
Lightfoot et al	Quasi-experimental	Good	28 delirium patients included in the preintervention arm and 33 patients at the intervention arm.	Real-time CDS alert that notifies pharmacist of delirium patient that meet recommendation criteria	Preintervention	Quality of care: compare the delirium incidence, length of stay, and ventilator duration between CDS and control group	(+) CDS group had a nonsignificant trend in decreased incidence of delirium, ICU length of stay, and ventilator duration. (+) CDS group had a significantly shorter hospital LOS.	Statistically significant

(*Continued*)

Table 3 (*Continued*)

Mansour et al	Quasi-experimental	Good	Any admitted patient who can potentially develop hyperkalemia.	High K level alert CDS that notifies pharmacists when a drug order will further increase K level	Preintervention	Safety: effect of a hyperkalemia ADE alert	(+) 48:14 pre-CDS; post-CDS patients had hyperkalemia that required treatment.	Statistically significant
McCoy et al	RCT	Good	396 patients with an acute 0.5 mg/dL change in serum creatinine over 48 hours and a nephrotoxicity or renally cleared medication order.	Web-based dynamic surveillance CDS monitors AKI by clinical pharmacists	Preintervention (patient with no surveillance tool)	Safety: AKI-related ADEs and potential ADEs within the CDS group compared with control group	(0) No statistical difference was observed between intervention and controlled group	NS
García-Molina Sáez et al	Quasi-experimental	Good	321 patients admitted in the cardiopneumology unit during the study period	"Medication history documentation" CDS integrated with electronic clinical history	Preintervention	Quality of care: CDS intends to decrease medication reconciliation error	(+) The mean number of reconciliation errors per patient: preintervention, 4.4 ± 3.2; during intervention, 1.8 ± 2.6; postintervention, 3.9 ± 3.7	Statistically significant
O'Sullivan et al	RCT	Good	1,833 patients aged >65 years admitted to specialist services	CDS with structured pharmacist review of medication (SPRM) to prevent ADR	Preintervention (standard pharmaceutical care without CDS)	Safety: ADR risk reduction between CDS and control group	(+) Provider implemented 54.8% of SPRM/CDSS prescribing recommendations. Ninety-one ADRs occurred in 78 control patients (20.7%) compared with 61 ADRs in 50 CDS group patients (13.9%), an absolute risk reduction of 6.8%.	Statistically significant
Wilson et al	RCT	Good	2,393 patients ≥18 years old with stage 1 or greater acute kidney injury	Current SCr-based AKI alert CDS sends notification to providers	Preintervention	Safety: ranking of clinical outcomes, maximum relative change in creatinine, dialysis, and death, within 7 days of randomization	(0) There was no difference between the two groups comparing the creatinine, dialysis, and death at 7 days.	Statistically significant
Kan et al	Quasi-experimental	Good	332 patients receiving IV antibiotics during the entire study period	CDS converting IV antibiotics to PO dose per pharmacist	Preintervention	QUM: assessing antibiotic IV–PO conversion rate before and after CDS implementation	(+) IV–PO conversion rate was 29% (preintervention), 35% (1 month postintervention), 71% (3 months post), and 74% (15 months post)	Statistically significant

Abbreviations; ADE, adverse drug event; ADR, adverse drug reaction; AKI, acute kidney injury; CDS, clinical decision support; CDSS, clinical decision support system; DDI, drug–drug interaction; eGFR, estimated glomerular filtration rate; ICU, intensive care unit; IV, intravenous; LOS, length of stay; PO, per oral; RCT, randomized controlled trial; SCr, serum creatinine.
Note: "+" meaning that the study favored the CDS intervention. "−" meaning that the study favored the control group. "0" meaning that there was no difference between the intervention and the control groups. "NS" meaning that the study did not conduct any statistical analysis or that there was no statistically significant data reported for the specified result. "QUM" meaning quality use of medication.

CDS Intervention Analysis

Eight studies significantly favored the CDS intervention[25,26,28,29,31–33,35]; 20% of the studies presented results that favored the CDS intervention without statistical significance[21,23,27]; 13% of the studies favored the control groups[22,24]; and 13% of the studies showed that the CDS interventions had no difference compared with the control group.[30,34] One study[24] favors pharmacists' check over CDS; however, this was explained by the authors that the CDS was self-developed and lacks a high level of specificity for drug–drug interactions (DDIs).

CDS interventions covered a wide range pharmacists' practice, including dynamic monitoring, drug safety in low kidney function patients, medication safety in patients with QT prolongation, dosing calculation, medication reconciliation, and general medication use and safety. Eleven of the 14 studies examined CDS application outside medication verification.[21,23,27–35] Among the 11 studies, 82% presented results that favored the CDS intervention with statistical significance,[21,23,27–29,31–33,35] 18% of the studies showed that the CDS interventions had no difference compared with the control group,[30,34] and no study favored the control group.

Discussion

This study demonstrated that CDS interventions developed for clinical pharmacists can improve health care outcomes. Notably, all studies that evaluated quality use of medication and quality of care showed improved outcomes. Moreover, CDS seems to be evolving with clinical pharmacists' roles, since the majority of studies evaluated an intervention outside order verification tasks.

When compared with CDSs in other settings, studies conducted in community pharmacy practice examined workflow consequences, interactions with patients more frequently, and relied less on EHR information, such as laboratory results.[15,36] Previous studies have examined CDS that supports prescribing in community and hospital pharmacy settings.[13,36] These studies concluded that workflow disruption and alert fatigue were major issues causing pharmacists to ignore CDS alerts and prompts. In the present review, we did not identify or conclude that workflow or alert fatigue was a problem. The lack of alert fatigue discussion in the included studies may be the result of the inpatient setting where patient data can be used to refine alert triggers, making alerts more specific. However, we do believe that alert fatigue is still an issue for pharmacists in the inpatient setting given the amount of CDS.[37]

One of the aims of this review was to examine how CDS is meeting the need of clinical pharmacists providing patient care. We found the majority of CDS interventions still focus on drug dosing, DDIs, and identifying or preventing adverse effects; however, we did find CDS interventions that have expanded to other clinical areas, such as managing acute kidney injury, and managing cardiovascular diseases. Also, CDS interventions supported specialized services in the emergency department, geriatric wards, trauma units, and other units.[9–11,15–19,21,22] These findings suggest that CDS is supporting specialized and decentralized pharmacists' roles in a variety of clinical domains in hospital departments.

Concerns remain on whether advanced CDS systems will replace pharmacists and reduce the number of pharmacy jobs. Based on the included studies, this does not seem to be the case as the majority of CDS interventions were basic alerts and prompts. Two studies used CDS to calculate antimicrobial dosing, but the ultimate decision was still based on pharmacists' discretion. There were no signs that implementation of CDS could replace clinical pharmacists, rather it is more likely that CDS is helping pharmacists increase their efficiency and patient safety.[38]

Limitations of this study should be noted. First, we were unable to conduct meta-analysis due to the heterogeneity of included studies. Second, we only queried studies published in three databases, which means there could be other published (or unpublished) studies that were not included. Finally, the majority of the studies showed a benefit from using CDS, which suggests publication bias may be present.

Conclusion

With more than 73% of studies examining CDS outside medication verifications and 82% of studies favoring the intervention, these findings suggest CDS implementations targeted toward clinical pharmacists have been increasing and improving as pharmacists' roles are becoming more clinical and patient-orientated. We anticipate that as the clinical pharmacy's role expands into more specialized health care fields, CDS interventions will also expand to support pharmacists and improve patient care.

Clinical Relevance Statement

This review showed that between 2009 and 2020, multiple studies examined clinical pharmacist related nonverification CDS and showed positive results that the CDS facilitates pharmacist's workflow in clinical settings. These CDSs were developed to accommodate the expanding roles of pharmacists. This review has indicated continuous progress for pharmacists to contribute in clinical patient care and makes pharmacist an important member in medical interdisciplinary team.

Multiple Choice Questions

1. Which of the following pharmacists' roles can be best facilitated by inpatient CDS systems (up to 2)?
   a. Pharmacists supervise the medicine supply chain.
   b. Pharmacists counsel patients on safe and effective medicine use.
   c. Pharmacists advise other health care professionals about safe and effective medicine use.
   d. Pharmacists monitor patient's health conditions and determine safety and efficacy of their current medication.

Correct Answer: The correct answers are options a and d. CDS systems can be implemented to monitor patient's health conditions or decrease medicine cost. CDS cannot replace pharmacists to counsel patients or advise health care professionals.

2. Which of the following is not a keyword used to determine included studies of this review?
   a. Pharmacist
   b. Computerized
   c. Clinical
   d. Doctor

Correct Answer: The correct answer is option d. This study reviews CDSs used by pharmacists in inpatient/clinical settings. Doctors are not part of the inclusion criteria.

Protection of Human and Animal Subjects

There were no human subjects involved in this project.

Conflict of Interest

None declared.

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