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Review

Review

Electronic tools to support medication reconciliation: a systematic review

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ABSTRACT

Objectives: Medication reconciliation (MedRec) is essential for reducing patient harm caused by medication discrepancies across care transitions. Electronic support has been described as a promising approach to moving MedRec forward. We systematically reviewed the evidence about electronic tools that support MedRec, by (a) identifying tools; (b) summarizing their characteristics with regard to context, tool, implementation, and evaluation; and (c) summarizing key messages for successful development and implementation.

Materials and Methods: We searched PubMed, the Cumulative Index to Nursing and Allied Health Literature, Embase, PsycINFO, and the Cochrane Library, and identified additional reports from reference lists, reviews, and patent databases. Reports were included if the electronic tool supported medication history taking and the identification and resolution of medication discrepancies. Two researchers independently selected studies, evaluated the quality of reporting, and extracted data.

Results: Eighteen reports relative to 11 tools were included. There were eight quality improvement projects, five observational effectiveness studies, three randomized controlled trials (RCTs) or RCT protocols (ie, descriptions of RCTs in progress), and two patents. All tools were developed in academic environments in North America. Most used electronic data from multiple sources and partially implemented functionalities considered to be important. Relevant information on functionalities and implementation features was frequently missing. Evaluations mainly focused on usability, adherence, and user satisfaction. One RCT evaluated the effect on potential adverse drug events.

Conclusion: Successful implementation of electronic tools to support MedRec requires favorable context, properly designed tools, and attention to implementation features. Future research is needed to evaluate the effect of these tools on the quality and safety of healthcare.

Key words: medication reconciliation, health information technology, quality improvement, continuity of care, patient safety

INTRODUCTION

Medication management continuity is a worldwide patient safety concern and a very complex task[1,2] requiring communication and information-sharing among providers, patients, and families across different settings.[3] Patients are therefore at risk for medication discrepancies during transitions from one care setting to another.[4,5]

These discrepancies – unexplained differences among documented regimens across different sites of care[6] – can lead to a prolonged hospital stay, early readmission, unplanned visits to the emergency department,[4] and even death.[7]

Medication reconciliation (MedRec) is a formal and collaborative process of obtaining and verifying a complete and accurate list of a patient's current medicines[8] to ensure that precise and comprehensive medication information is transmitted consistently across care transitions.[9] Several leading organizations worldwide, such as the World Health Organization, The Joint Commission, the Institute for Healthcare Improvement, the National Institute of Clinical Excellence, and the Canadian Patient Safety Institute, have campaigned for the implementation of MedRec. Despite this, most healthcare organizations are struggling to develop efficient tools and effective implementation strategies.[3,7,10,11] Successful MedRec is resource-intensive: it is time-consuming, requires multidisciplinary collaboration, and imposes a cognitive burden on clinicians that could be relieved by the use of technology.[2,9,12]

Efforts to reduce medication discrepancies using health information technology (IT) have recently emerged[13] and different organizations have clearly indicated that technology to support the MedRec process will be essential for its successful implementation across the healthcare system. Electronic medication reconciliation (eMedRec) tools are computerized tools used to help support MedRec processes. These tools allow healthcare providers to compare the best possible medication history to orders and to identify discrepancies by displaying medication lists and to resolve discrepancies by providing the following options: continue, change, or discontinue a medication.[14]

Whereas previous systematic reviews summarized the available evidence on MedRec,[4,5] and a few narrative or scoping reviews have addressed the use of IT in MedRec,[3,15,16] to our knowledge, there has been no systematic review of electronic tools (e-tools) to support MedRec. Bassi et al.[3] performed a scoping review of primary studies published up to March 2009 that looked at the use of IT in the MedRec process. They found that IT was mainly used to obtain medication information, but very few systems at that time used a fully enabled eMedRec tool. However, the authors reported that promising applications were being developed to support the entire MedRec process. Original studies have since described the development and evaluation of such tools.[2,9,12,17,18] We therefore aimed to systematically review the evidence about e-tools that fully support MedRec, by (1) identifying tools; (2) summarizing their characteristics with regard to context, tool, implementation, and evaluation; and (3) summarizing key messages for successful development and implementation of eMedRec tools.

MATERIALS AND METHODS

Data Sources and Searches

We performed a systematic search of articles published from database inception up to October 2014 using PubMed, the Cumulative Index to Nursing and Allied Health Literature, Embase, PsycINFO, and the Cochrane Library. We developed the search strategy in consultation with a medical librarian who is experienced in systematic review. We used an iterative process of building a search strategy, running the search, searching the relevant articles for additional terms, and then rebuilding the search strategy. Our search strategy consisted of a combination of subject heading terms and free-text words combining two groups of themes: (1) continuity of care – medication reconciliation, and (2) IT. The final search strategy for PubMed (see Supplementary Appendix I) was then adapted for each database. The other queries can be provided on request.

To identify additional eMedRec tools (both those about which reports have been published and those that have not), we (1) scanned the reference list of included studies and relevant reviews; (2) searched patent databases, ie, the FamPat database (Questel Orbit) and the Espacenet database with the help of Picarre Intellectual Property; (3) searched recent grey literature reports referring to eMedRec;[14,19] and (4) scanned the list of articles that subsequently referenced the papers included using Scopus (last search November 2015). More information is available on request.

Study Selection

Eligible reports included original full-text articles, proceedings, and patents describing e-tools that supported all three steps of the MedRec process, namely, (1) gathering the best possible medication history, (2) comparing the different lists in order to identify discrepancies, and (3) resolving those discrepancies. Reports had to contain both a description of the tool and some kind of evaluation, whether regarding a health outcome, provider satisfaction, adherence, utilization, or efficiency. Proceedings and patents were also included – in addition to original full-text articles – because these are frequent forms of publication for health IT tools. If several patents had been written for the same tool, we used the most recent. Because the information available in proceedings is limited, for potentially eligible proceedings, we contacted authors by e-mail to request additional information and/or clarification, using a standardized form and screenshots of the tool. This additional information was then used for study selection and data extraction. If three e-mails to the proceedings authors went unanswered, the proceedings were then excluded.

We excluded reports that did not include a description of the tool, reports referring to an e-tool that only partially supports the MedRec process, reports on the reconciliation of specific drugs and classes, review papers and commentaries, and non-English-language reports. There were no restrictions regarding study type, setting, or type of care transition.

Two reviewers (B.K. and S.M.) independently evaluated the eligibility of reports by first examining their titles and abstracts, and then the full text of reports identified as potentially eligible for this study. Disagreements were resolved by discussion, and, when consensus could not be reached, a third author (A.S.) was consulted and a decision was made. Eligibility was delayed for proceedings and for studies reporting data incompletely, pending author contact (see above).

Data Extraction and Quality Assessment

A standardized data extraction form (Supplementary Appendix II) was created based on (1) the Effective Practice and Organization of Care data collection form,[20] (2) forms used in previous systematic reviews,[3,4,21] and (3) reports from the gray literature on eMedRec.[14,19] The form was piloted on four reports by 3 reviewers (A.S. , B.K., and S.M.) to ensure completeness, clarity, and reliability. Data extraction included study design (using a recently published categorization of improvement interventions[22]) and description of context, tool, implementation and evaluation, and lessons learned as reported by the authors. Two reviewers (S.M. and B.K.) independently extracted data. Disagreements were resolved by consensus.

For each report, we evaluated quality in two complementary ways. First, the quality of reporting of the context, tool, and implementation/evaluation was evaluated with the criteria used in a recent systematic review of patient portals.[21] These criteria had been

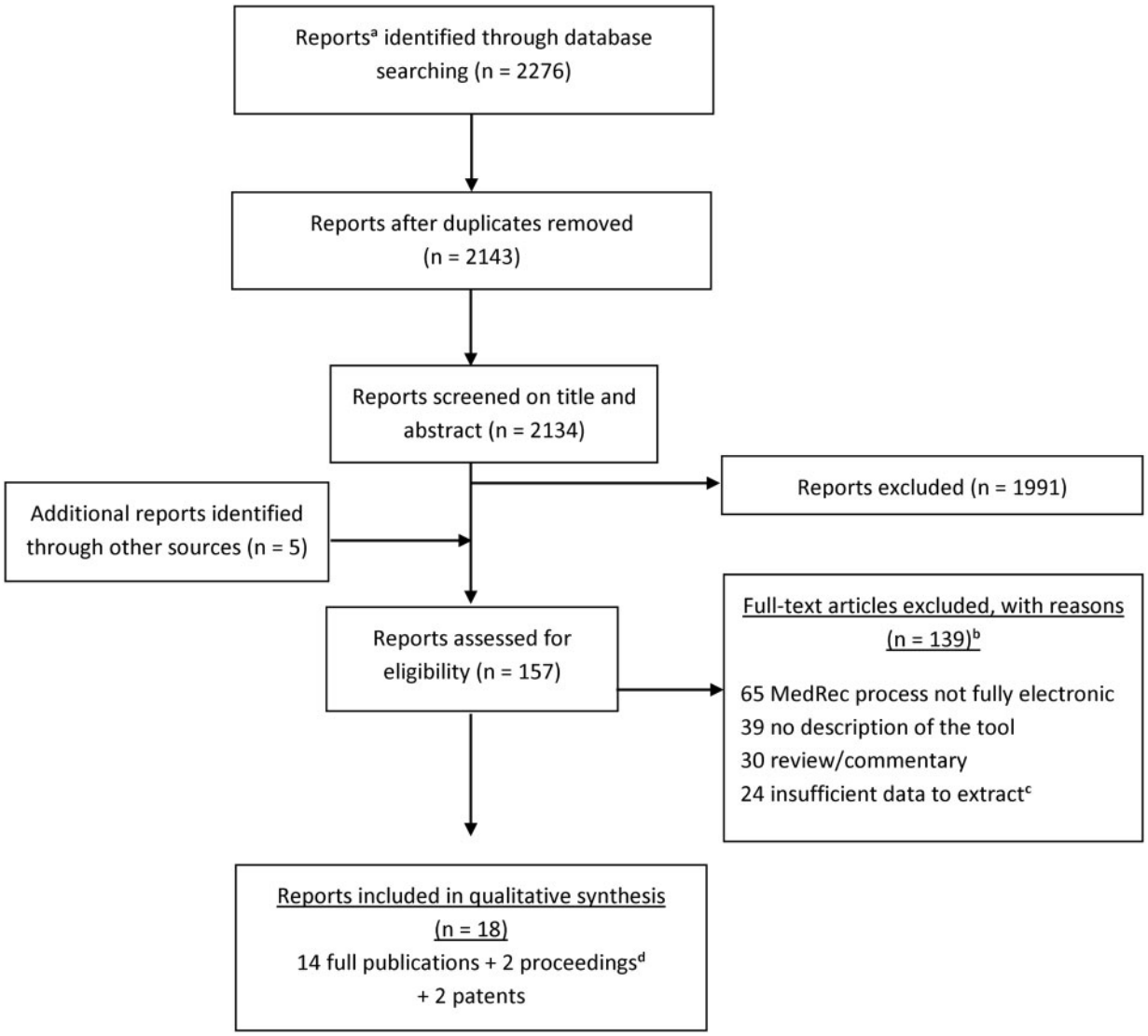

Figure 1. Search strategy and study selection. [a]Reports include full-text articles, proceedings and patents. [b]Reports could be excluded for more than one reason. [c]Insufficient data means: full text not available or unanswered request by authors of proceedings. [d]Proceedings were included if authors could send us relevant additional information so that publication met inclusion criteria and that data could be extracted.

modified from criteria developed to assess patient safety strategies, which included health IT applications.[23] Second, based on the Canadian *Paper to Electronic MedRec Implementation Toolkit*[14] and on the American Multi-Center Medication Reconciliation Quality Improvement Study (MARQUIS) toolkit to disseminate best practices in inpatient MedRec,[19] we listed the main ideal features needed to for a user-friendly and efficient eMedRec tool, and, for each report, we evaluated whether each feature was present.

Data Synthesis and Analysis

Due to the large variation in study types and measurements, a meta-analysis of the studies considered was not possible. Instead, we constructed evidence tables showing the characteristics and results for all included reports and critically analyzed the data. Reports that referred to a single eMedRec tool were grouped together. Finally, we compiled a summary of recommendations made by the authors of the included studies for the successful development and implementation of eMedRec tools. We categorized these factors as being relative to the tool, context, or implementation and used them to draw conclusions.

RESULTS

Study Selection

Overall, the search strategy yielded 2143 reports following duplicate removal, of which 1991 were discarded after examining the title and abstract (Figure 1). Of the 152 reports that were selected for full-text screening (or screening of additional information sent by authors, in the case of proceedings) and 5 additional reports identified through reference list searching, 18 met our inclusion criteria (14 published articles, 2 proceedings, and 2 patents). The main reasons for exclusion were (1) the tools described did not support all three steps of the MedRec process, and (2) the report lacked a description of the tool.

Table 1. Description of Studies and Main Results

e-Tool	Author, country, year	Point of investigation	Objective(s) of the study	Study class[a]	Main results of evaluation[b]
The PreAdmission Medication List (PAML) Builder	Poon, USA, 2006[1]	Admission, discharge	To describe the design of a novel application and the associated services that aggregate medication data from EMR and CPOE systems	Quality improvement project	A: 78% of patients had a PAML created. U: Users found the interface intuitive and many were able to use it without any training. Clinicians found electronic juxtaposition of the PAML with admission and or discharge order screens helpful.
	Turchin, USA, 2008[27]	Admission, discharge	To assess clinicians' attitudes toward eMedRec, their compliance and the factors that affect their efficiency and compliance	Effectiveness observational study	S: 39% of users were satisfied, 50% of users thought eMedRec helpful, 64% of users agreed eMedRec improves patient care. A: A planned action was recorded on admission for 69% of the medications listed in the PAMLs; users' prior compliance with using the tool was the main predictor of future compliance ($p < 0.0001$). U/E: 69% reported that it usually took them <10 min to build a PAML, users' experience and ease of use shortens the time to build a PAML.
	Schnipper, USA, 2009[28]	Admission, discharge	To measure the impact of an eMedRec intervention on medication discrepancies with the potential for harm	RCT	O: Significant decrease in potential adverse drug events (adjusted relative risk, 0.72; 95% CI, 0.52-0.99); no significant difference in healthcare utilization (readmission and visit to the emergency department). *A*: For 99% of patients, the PAML Builder application was used; a PAML was completed within 24 h of admission for 46% and prior to discharge for 75%.
A tool within the EMR to facilitate MedRec after hospital discharge	Schnipper, USA, 2011[32]	Post-discharge	To describe the design and implementation of the tool, attempts to improve use, informal feedback from clinicians, and generalizable lessons learned to maximize the usability of the tool and its impact on patient safety	Effectiveness observational study	S: Most clinicians were supportive of the tool, several clinicians asked for an interruptive reminder. A: The tool was used in 12–18% of eligible patients during the first 6 months, and in 41% for the last 6 months after implementing a pop-up reminder, clinical outreach, and education. U: Users identified several usability issues (eg, the way to invoke the tool was not obvious enough, confusion about whether they needed to act upon every medication discrepancy), and several actions were taken afterwards.
A tool for MedRec after hospital discharge with an (electronic) retrieval of community drugs and an (electronic) communication module	Tamblyn, Canada, 2012[7]	Discharge	To determine whether electronically enabled discharge MedRec reduces the risk of adverse drugs events, emergency room visits, and readmissions 30 days post-discharge compared with usual care	RCT protocol	O: Adverse drug events, emergency visits, hospital readmissions 30 days post-discharge.
MedRec application	Cadwallader, USA, 2013[2]	Outpatient	To design a MedRec application that could incorporate multiple data sources and convey information about patients' adherence to prescribed medications	Quality improvement project	U: Feedback of clinicians, IT professionals, pharmacists, and nurses were collected. Each prototype then underwent iterative revisions to incorporate their feedback. A final prototype was then created by incorporating the best features of each initial approach.

(Continued)

Table 1. Continued

e-Tool	Author, country, year	Point of investigation	Objective(s) of the study	Study class[a]	Main results of evaluation[b]
Twinlist	Markowitz, USA, 2011[12]	Post-discharge	To evaluate whether a systematic user interface design process will dramatically improve the efficiency and quality of MedRec process	Quality improvement project	U/E: Three tasks were analyzed via the KLM analysis: reconciling two identical medications, removing a medication, and editing its dosage. The number of actions, the number of required mental operations, and overall task completion time were lower for the prototype than either LHS RxPad or PAML.
	Plaisant, USA, 2013[9]	Discharge	To describe Twinlist, an interface that provides cognitive support for MedRec. To describe a series of variant designs and discuss their advantages or disadvantages. To report a pilot study.	Quality improvement project	U = Feedback from 20 users: the Twinlist spatial layout is a meaningful grouping and the multistep animation is helpful for learning (70%).
The Automated Patient History Intake Device (APHID)	Lesselroth, USA, 2009[24]	Outpatient	To describe project design and implementation, review preliminary findings on feasibility, and discuss the barriers to adoption encountered by the development team	Quality improvement project	A: 1371 patients used the APHID during the first month; 47% of eligible patients ($n = 8170$) used the APHID during the ensuing 6 months. S: Most staff reported that APHID helped with history collection; providers also felt overwhelmed with the new responsibility of MedRec, and some clinicians were reticent to address discrepancies that felt outside their content area. S/E: 67% patients believed the program improved their medication recall. U: Many providers felt that the volume of medications to review and formatting of medication lists made it challenging to quickly identify discrepancies needing action. U: 75% of patients thought the APHID was easy to use, 67% thought it was easy to navigate, 94% thought it was easy to understand.
	Lesselroth, USA, 2009[11]	Outpatient	To describe how a process for patients in the waiting room to use kiosk technology in providing their own medication histories was developed and implemented	Effectiveness observational study	O: 91% of cases with discrepancy, an average of 4.6 discrepancies per patient, and an average of 1.6 clinically significant or potentially lethal discrepancies. S: Nurses agreed that they possessed more accurate drug-dispensing information, and patients were occasionally dissatisfied when asked to review expired medications. A: 82% patients used the kiosk. U: Patients said the kiosk was easy to use and the medication pictures assisted with recall. E/U: The use of APHID by patients represents a nearly 50% reduction in nursing time dedicated to medication reconciliation activities.

(Continued)

Table 1. Continued

e-Tool	Author, country, year	Point of investigation	Objective(s) of the study	Study class[a]	Main results of evaluation[b]
	Lesselroth, USA, 2011[25]	Outpatient	To describe the development, administration, and findings of a survey intended to assess PCP perceptions of the tool in an effort to identify factors that can influence implementation	Effectiveness observational study	S: PCP have favorable attitudes toward MedRec and think it represents an important safety intervention, but 43% did not believe they had the necessary resources to manage discrepancies, and the majority of PCP favored the tool over usual care. U: 58% of the PCP indicated that they were familiar with the technology and had seen the tool output.
	Lesselroth, USA, 2012[10]	Outpatient	To evaluate the accuracy of the medication list produced using the software. To measure the incremental value of including medication pictures. To characterize the types and root causes of medication discrepancies detected using the software.	RCT protocol	E: Number of discrepancies, types, root cause, and severity.
	Lesselroth, USA, 2014[26]	Any	To describe the invention: APHID supporting medication reconciliation, clinic check-in, demographic and insurance data verification, and allergy review	Patent	NA
A MedRec view within the EHR displaying two columns: inpatient and outpatient medications' list	Vawdrey, USA, 2010[29]	Admission, discharge	To assess the impact of adopting the eMedRec process at a large academic medical center	Quality improvement project	S: Clinicians complained about the 30–60 s required for adding a medication and about the technical limitation concerning the conversion of Outpatient Medication Profile medications into inpatient orders. A: Usage of the eMedRec process <40% before the "hard-stop" intervention and above 96% 1 month after. E: Average number of medications contained in the Outpatient Medication Profile was <2 before implementing the eMedRec process and increased to 4.7 after.
A MedRec application launched from within the EHR	Bails, USA, 2008[30]	Admission, discharge	To describe the interdisciplinary process undertaken at a large academic medical center, to develop a full online MedRec program	Quality improvement project	A: In phase 1, MedRec was done for only 20% of patients. In phase 2, after providing feedback and making eMedRec mandatory, compliance rates achieved 95%.
Electronic pathway for MedRec	Lovins, USA, 2011[31]	Admission, transfer, discharge	To implement an eMedRec pathway to reduce medication errors happening after transitions of care	Quality improvement project	S: Patient, family, and staff reported a high level of satisfaction. A: Compliance rate was >90%. E/U: Staff perceived improvements in workflow, efficiency, and safety.

(Continued)

Table 1. Continued

e-Tool	Author, country, year	Point of investigation	Objective(s) of the study	Study class[a]	Main results of evaluation[b]
The Discharge Instruction element	Sherer, USA, 2011[33]	Admission, discharge	To determine the accuracy of the discharge medication list made with the Discharge Instruction element and given to the patient by comparing this list with the list dictated in the discharge summary	Effectiveness observational study	S: High level of provider satisfaction. A: Provider usage rates varied from 87–93%. E/U: 95% accuracy rate for information collected at admission, and eMedRec implementation reduced time spent completing the discharge work by 7 min.
Interactive Patient Medication List	Tripoli, USA, 2014[34]	NA	To describe the invention: system, methods, and techniques for presenting a medication list to a patient and for maintaining updates to the medication list	Patent	U: Feedback from pharmacists.

CI, confidence interval; CPOE, computerized physician order entry; eMedRec, electronic medication reconciliation; EHR electronic health record; EMR, electronic medical record; e-tool, electronic tool; IT, information technology; KLM, Keystroke-Level Model; LHS RxPad, Legacy Health System with RxPad record; MedRec, medication reconciliation; NA, not applicable; PCP, primary care provider; RCT, randomized controlled trial; RCT protocol, description of RCT in progress.

[a]Study class: According to Portela's published improvement interventions categorization.[22]

Quality improvement projects: Project is set up primarily as an improvement effort, to learn what works in a local context. It is typically motivated by a well-defined problem and oriented towards a focused aim. Plan-Do-Study-Act cycles are often applied, allowing for testing incremental, cyclically implemented changes, which are monitored through statistical process control.

Effectiveness studies:

1. RCTs
2. Quasi-experimental designs: The intervention is implemented and followed up over time, ideally with a control.
3. Observational (longitudinal) studies: The implementation of the intervention is observed over time.

[b]Results: O = health outcomes; S = satisfaction; A = adherence; U = utilization; E = efficiency.

Table 2. Description of the Context, System, Implementation and Presence of Ideal Features of eMedRec Tools

e-Tool	Author, country, year	Context	Tool						Implementation/Evaluation						
		Description criteria[a]	Description criteria[b]	Integrated into the workflow?	Linked to other electronic systems?[c]	Automatic highlighting of discrepancies?	Reason for stopping medication written?	Different possibilities for organizing medication lists?	Description criteria[d]	eMedRec process with reminder or mandatory?[e]	Other specific features associated?[f]	Use of different prototypes?	Usability evaluated?	Routine use?	Evaluation of users' compliance with eMedRec?
The PAML Builder	Poon, USA, 2006[1]	>3	>3	+	•	–			≥2		+	+	+	+	+
	Turchin, USA, 2008[27]	>3	>3	+					≥2				+	+	+
	Schnipper, USA, 2009[28]	>3	>3	+	•	–			≥2				–	+	+
A tool within the EMR for MedRec after hospital discharge	Schnipper, USA, 2011[32]	>3	2	+	⊙	+			≥2	⊙	+	+	+	+	+
MedRec after hospital discharge	Tamblyn, Canada, 2012[7]	>3	>3	+	•	+	+		≥1		+	–	–	–	–
MedRec application	Cadwallader, USA, 2013[2]	2	>3	–	•	+		+	NA		+	+	+	–	–
Twinlist	Markowitz, USA, 2011[12]	0/1	2	–	○	+			NA			+	+	–	–
	Plaisant, USA, 2013[9]	2	2	–	○	+		+	NA			+	+	–	–
APHID	Lesselroth, USA, 2009[24]	>3	2	+	•	–			≥2			+	+	+	+
	Lesselroth, USA, 2009[11]	> 3	> 3	+	⊙	–			≥2				–	+	+
	Lesselroth, USA, 2011[25]	> 3	0/1	+	•	–						+	+	+	–
	Lesselroth, USA, 2012[10]	> 3	0/1	+	•	–							–	+	–
	Lesselroth, USA, 2014[26] (patent)	NA	>3	NA	•	+	+		NA		+	NA	NA	NA	NA
A MedRec view within the EHR displaying two columns	Vawdrey, USA, 2010[29]	>3	2		•					•		+	–	+	+
MedRec application launched from within the EHR	Bails, USA, 2008[30]	>3	2	+	•	–			≥2	•		+	–	+	–
Electronic pathway for MedRec	Lovins, USA, 2011[31]	>3	NA	+	•/⊙	+		+	NA	⊙		+	+	+	+
The Discharge Instruction element	Sherer, USA, 2011[33]	>3	2	+	•/⊙	+		+	≥1	○		–	+	+	+
Interactive Patient Med List	Tripoli, USA, 2014[34]	NA	>3	NA	•	+	+	+	NA		+	NA	NA	NA	NA

APHID, Automated Patient History Intake Device; CPOE, computerized provider order entry; e-tool, electronic tool; EHR, electronic health record; eMedRec, electronic medication reconciliation; EMR, electronic medical record; IT, information technology; MedRec, medication reconciliation; NA, not applicable. PAML = PreAdmission Medication List Builder.

+ = YES; – = NO (as reported by the authors). An empty box = not reported by the authors.

[a]Description of the context: >3 criteria, 2 criteria, 0/1 criteria: Size, location, or academic status; Financial status, or past IT experience; Information about culture, teamwork, and leadership; Existing external factors: for example, regulatory requirements, presence in the external environment of payments or penalties, such as pay-for-performance or public reporting.

[b]Description of the tool: >3 criteria, 2 criteria, 0/1 criteria: different functionalities included; what/how the tool interfaces with the EMR; what is required for the consumer to operate it. Description items had to be sufficiently detailed so that it could be "replicated."

[c]Linked to ≥3 other systems = •; Linked to 1 or 2 other systems = ⊙; Not linked to any other systems = ○ (eg, CPOE, EMR, pharmacy claim).

[d]Description of the implementation: number of components beyond "staff education": ≥2, ≥1, 0. Possible components are: description of barriers and facilitators, audit and feedback, presence of "champions" (quality improvement leaders) responsible for implementation, assessment of impact on workflow, and tailoring/change management.

[e]Mandatory = •; Reminder = ⊙; Nothing = ○.

[f]Other specific features associated: review appropriateness of medication, post-discharge communication with patient, and or with other healthcare provider (by e-mail/printed list), possibility to reconcile only part of the medication list, decision support functionality (not specifically related to medication reconciliation), existing of different way of presenting medication regimen to the different users according to the needs of each (physician, patient, pharmacist), section for drug event report via e-mail.

Description of Studies

The 18 reports included in this study were published over the last 10 years and describe 11 different eMedRec tools. Five reports were about the Automated Patient History Intake Device (APHID),[10,11,24–26] three were about the PreAdmission Medication List Builder,[1,27,28] two were about the Twinlist,[9,12] and there was one report about each of the other tools. According to Portela's classification, eight reports were quality improvement projects,[1,2,9,12,24,29–31] five were effectiveness observational studies,[11,25,27,32,33] and three were randomized controlled trials (RCT)[28] or RCT protocols.[7,10] Because the two remaining reports were patents, we could not classify them in one of these categories. Table 1 summarizes the characteristics and main results of the reports included in this study. The quality of the reports' description of the context, the tool, and the implementation are reported in Table 2.

Context of Development

Ten of the tools reported on were developed in the United States and one was developed in Canada.[7] Except for the Interactive Patient Medication List,[34] all the tools were developed in academic environments (ie, academic hospitals or universities). Tools were almost equally implemented at admission and discharge[1,27–31,33] or in outpatient clinics.[2,10,11,24,25,32] Five of these tools[1,10,11,24,25,27,28,30,31,33] were reported as having been developed in hospitals promoting patient safety culture, four reports[2,7,29,32] did not include information about this culture, and, for the two last tools, this criterion was not applicable.[9,12,34] When patient safety culture was mentioned, the quality improvement team insisted on the need for interdisciplinarity or teamwork for developing and implementing eMedRec. One study highlighted the importance of the context of development.[28] In that case, the intervention took place in two hospitals, and a statistically significant decrease in potential adverse drug events was reported in one of the two hospitals. The authors hypothesized that differences in context and implementation (level of publicity and nurses' involvement) probably contributed to the differences observed.

Characteristics of the Tools

Seven[1,7,10,11,24,25,27,28,30–33] of the tools reported on were integrated into the organization's/clinicians' workflow. All the tools, except the Twinlist,[9,12] used electronic data from different sources, such as pharmacy claims data, electronic medical records, and computerized physician order entry (CPOE) to collect the medication history and identify discrepancies. Despite the fact that these characteristics are considered by the United States and Canadian toolkits as ideal features for eMedRec tools,[14,19] only half[2,7,9,12,26,31–34] of the 18 reports included in this study highlighted medication discrepancies, only 5 of the 18 reports[2,9,31,33,34] offered various possibilities for organizing medication lists differently, and only 3[7,26,34] documented reasons for stopping medication (Table 2). Other functionalities were implemented in order to reduce the time needed to complete tasks and cognitive burden: displaying medication lists side-by-side[2,7,9,12,29,33] and using different filters[2,9,31,33,34] for sorting unreconciled medications. Additional functionalities to make the eMedRec process more efficient included gathering information from multiple sources;[1,2,10,11,25,26,28–30,34] giving access to detailed information on prescribing, dispensing, etc.;[7,34] communicating the reconciled medication list easily and quickly to other providers;[7,24,34] linking decision support systems (eg, systems supporting decision to admit patients, supporting drug-drug interaction detection);[34] and creating a link with an automatic input to the CPOE.[25,30,34] Plaisant's team[9,12] also developed animations to help novices master the tool they reported on.

With regard to the availability of the tools on the market, Twinlist is available as an open-source program,[9] the Discharge Instruction element is commercially available,[33] and the APHID[10,11,24–26] team is working on a prototype for a national enterprise deployment within the Veterans Health Administration. In addition, a few tools can be embedded in electronic health record (EHR) products such as CERNER,[33] Eclipsy Sunrise EHR,[29] and Siemens EHR.[31] Finally, two additional tools will probably be commercially available in the next few years.[7,34]

Lesselroth's team involved patients, considered as a group of specific users, in the MedRec process.[10,11,24] Patients reviewed their composite list of medications with the eMedRec tool, using a kiosk situated in the lobby, and the program automatically charted patient response in the EHR. Cadwallader also planned to involve patients in this process.[2]

Implementation and Evaluation

To develop an eMedRec tool, most of the research teams used different prototypes with Plan-Do-Study-Act cycles to improve the tool and adapt it to users' needs and to workflow (Table 2). These were classified as quality improvement projects (Table 1). Although teams explained that they needed several years to develop the tool before it was finally put into routine use, none mentioned the number of prototypes they developed to arrive at the final tools.

Due to the variability of the objectives recorded and to missing information, results were difficult to compare (Table 1). Nevertheless, the main measures of evaluation were related to usability,[1,2,9,11,12,24,25,27,31–33] adherence to the tool,[1,11,24,27–33] and user satisfaction.[24,25,27,29,31–33]

Usability was evaluated in different ways: time saved by clinicians,[9,27,33] workflow improvement,[11,31] ease of use,[1,9,11,12,24,25,27] and understanding of the tool.[9,24,25] In several quality improvement projects, usability issues that were identified led to the implementation of improvements in a revised prototype of the tool.

Regarding adherence, some authors[1,28,30,32] looked at the number of patients with a medication list created or reconciled, while others measured the proportion of clinicians using the tool[29,31] or the proportion of patients connecting to the tool.[11,24] When tools were in routine use, several teams struggled with user adherence and therefore implemented specific incentives (Table 2). Three authors reported significant improvements in adherence after implementing a reminder[31,32] or even a hard stop.[29,30] Other steps taken in support of tool adoption included elaborating workflow models[1,10,11,24,28] aimed at integrating the new e-tool in the most efficient way possible and defining the responsibilities[1,7,10,11,24,28–30] of each actor. With regard to the impact of eMedRec on health outcomes, Schnipper reported that an eMedRec intervention significantly decreased the risk of potential adverse drug events.[28] In her RCT protocol, Tamblyn has planned to measure adverse events, emergency visits, and hospital readmissions.[7] Finally, Lesselroth will evaluate the impact of eMedRec on medication discrepancies.[10]

Recommendations for the Successful Development and Implementation of an eMedRec Tool

Because objectives varied considerably from one report to another, the authors of the reports included in this study arrived at a variety of conclusions. Nevertheless, each team produced a list of

Box 1. Recommendations Made by Authors for the Successful Development and Implementation of eMedRec Tools

Recommendations concerning the context of development

Adapt the tool workflow to the habits of frontline users[1,7,24,25,27,28,30]

Offer the possibility of invoking the application from multiple points in the workflow,[1] regardless of the EMR medication list status[32]

Define the roles of each frontline user in the eMedRec process[11,24,27,30]

Ensure support from clinical/hospital leaders[1,30] and a suitable organizational climate[24,25,30]

Persuade frontline users, especially clinicians, of the importance of MedRec[30]

Engage patients in the MedRec process[2,24]

Recommendations concerning functionalities and development of the tool

Concerning the tool in general

- Develop tool features and design interfaces in an iterative manner, driven by the clinical processes[9,12,27]
- Use design guidelines for designing health IT; identify and use individual design components (eg, animation, groupings)
- Choose a design that matches the overall design philosophy of the EHR user interface[9]
- Use prototypes and pilots[27]
- Involve patients as collaborative partners in developing the tool[11]
- Do not anticipate users' needs[1]
- Medication information needs to be entered in coded format[27]

Gathering the best possible medication history

- Use information from different sources[1,2] and gather this information electronically by linking the eMedRec tool to medication lists of other systems (EMR, CPOE, EHR, pharmacy claims, etc.)[25,29,30]
- Aim for interoperability between different medication lists, with the possibility of automatically charting the reconciled list in the EHR/CPOE[25,30]
- Develop easy-to-use technology (drug pictures, prescribers' information next to each medication)[11,25,29]
- Do not overautomate the tool[1]

Identification of discrepancies

- Develop robust detection of discrepancies[11]
- Develop technology that is easy to use and reduces cognitive burden: use animations and offer different filters for classification; help providers to recognize, contextualize, and manage medication discrepancies[2,9,12,25,29]

Resolving discrepancies

- Explore and develop decision support algorithms to help providers identify clinically meaningful discrepancies[2,11]
- Develop easy-to-use technology: allow manual verification of all medication,[32] allow partial reconciliation,[24] document reasons for all reconciliation actions taken,[32] enable inter-facility provider communication of discrepancies,[11] foresee tight integration with the CPOE system[27,29,30]

Recommendations concerning the implementation of the tool

Provide education and support: regularly train users and local leaders, provide on-site support[1,7,25,27,32]

To improve compliance: introduce reminders or hard stop,[27–30,32] reduce the time needed to reconcile medication,[29] have measurable compliance rates to enable ongoing feedback,[28,30] collect users' suggestions[1,25,27,30]

Compare electronic lists to a gold standard structured medication history[10,24]

Conduct usability testing[2,12,29] and test the software (reliability + interoperability) in selected and disparate settings[10,24]

Focus on efficiency in addition to clinical improvements[12]

Establish a process for referring recurrent errors and discrepancies for failure analysis and potential system-based intervention[11]

Assess the generalizability of your findings using comparable data from other hospitals using eMedRec tools[29]

CPOE, computerized physician order entry; EHR, electronic health record; EMR, electronic medical record; eMedRec, electronic medication reconciliation; IT, information technology; MedRec, medication reconciliation.

recommendations for the successful development and implementation of an eMedRec tool. These are summarized in Box 1.

DISCUSSION

Main Findings

To our knowledge, this is the first systematic review of e-tools to support MedRec. We have identified 11 tools that support the entire MedRec process, 7 of which are in routine, daily use.[1,10,11,24,25,27–33] This adds valuable information to recent literature reviews that identified a limited number of studies of IT support for MedRec. Most studies referred to e-tools that supported some, but not all, steps of the MedRec process.[3,4] We mainly found quality improvement studies and observational effectiveness studies that showed positive results overall in terms of usability,[1,2,9,11,12,24,25,27,31–33] satisfaction,[24,25,27,29,31–33] and adherence.[1,11,24,27–33] However, evidence remains insufficient about the impact of eMedRec tools on the quality and safety of healthcare.

Implications for Practice

Recent reports summarized the ideal features and functions an eMedRec tool should include.[14,19] None of the tools identified seem to include (or to have described whether or how it included) all of these features and functions, but these manuals were published after all of the reports we identified.

Our data confirm that the success of developing and integrating technical solutions to support MedRec is strongly dependent on attention to implementation processes and extensive usability testing.

Implementation Processes

Successful eMedRec requires a concerted quality improvement effort, of which IT is but one component. To be embraced by most users, eMedRec tools need appropriate national and institutional environments. At the national level, all the tools identified were developed in the United States and Canada, where national campaigns and incentives have encouraged MedRec progress since 2005.[35,36] Accordingly, the applicability of our results to other healthcare

systems with different environments, cultures, and use of health IT, including those in Europe, cannot be guaranteed. Three studies carried out in Spain with one eMedRec tool have been published recently,[18,37,38] but additional studies will need to be conducted in environments outside the United States and Canada.

At the institutional level, we found that endorsement by quality improvement leaders,[1,25,30] highly integrated care, past experience of technology, and a culture of fostering patient safety enhanced the adoption of eMedRec into routine use. Persuading frontline users and improving awareness among clinicians of the importance of eMedRec (eg, by specific clinical vignettes) is essential to successful implementation.[30] Staff education (eg, providing training on its use, educational handouts, or online materials) and on-site support were repeatedly recommended by researchers.

Despite favorable organizational cultures, institutions have struggled to reach user compliance rates above 50%.[14,29,30,32] Additional measures that were reported to be helpful in increasing compliance were (1) workflow redesign[1,25,27] and precise definitions of roles and responsibilities,[24,27,30] (2) equipping the tools with reminders[31,32] or hard-stop systems,[29,30] and (3) reducing the time needed to reconcile medication.[29] As with non-electronic processes, successfully implementing eMedRec requires multidisciplinary teamwork.[31,39,40]

Extensive Usability Testing

Usability testing is the most commonly used evaluation method for assessing user interactions with health IT. Clinical processes have to drive IT development and design.[27] Usability tests ensure that clinicians and other healthcare professionals have an opportunity to evaluate and provide feedback on eMedRec systems' functionality, usability, and workflow.[14,25,27,30] Most reports evaluated some components of usability.[1,2,9,11,12,24,25,27,31–33] Evaluations of Twinlist were unique in that they purposively evaluated cognitive support of MedRec through interface design.[9] In an experimental study[41] published after we carried out our systematic search, the authors found that Twinlist could significantly improve the performance and safety of MedRec tasks. Their results should certainly help other developers and researchers, including EHR vendors, improve their own design.

Applicability to Commercially Available Tools

Three of the eleven tools that were identified in the present review are available as an open-source program (Plaisant[9]) or commercially available (Vawdrey[29] and Sherer[33]). Two additional tools are aiming to get into the market.[7,26,34] Many other MedRec tools (either stand-alone or embedded in EHRs) are commercially available. Unfortunately, no eligible reports on these other tools were found by our search strategy. In order to explore the applicability of our results to these tools, we contacted 8 eMedRec software vendors referred to in the MARQUIS toolkit[19] and 16 EMR vendors and asked them to provide information on their MedRec tools. Three reminders were sent. Seventeen vendors did not respond, and most responders did not want to share detailed information. In addition, we searched for information on the vendors' websites.[42–65] It seems that many tools are clearly integrated in the clinician's workflow and tightly linked to CPOE and other decision support systems. Many vendors claim that users gain time and accuracy by using their MedRec tool. Nevertheless, information concerning the tool's characteristics – such as automatically highlighting discrepancies, making it possible to document the reason for stopping/modifying medication, offering different options for the organization of the medication list – was neither provided by vendors, nor found on their websites. At least nine EHRs had developed a patient portal,[50–52,54,57,61–63,65] but patient input is apparently not used to inform the MedRec tool's consolidated list (a synthesis table can be found in Supplementary Appendix III).

Implications for Research

As most of the tools reported on had only recently been implemented, the evaluations of these tools were mainly limited to measures of usability,[1,2,9,11,12,24,25,27,31–33] user adherence,[1,11,24,27–33] and satisfaction.[24,25,27,29,31–33] We found only one RCT that evaluated the impact of eMedRec on clinical outcomes, namely potential adverse drug events.[28]

Future studies should correlate the specific features of MedRec tools to their efficacy in improving the identification and resolution of medication discrepancies. This could help with considering which features are the most important. Validated measures should be used to assess usability, such as the Questionnaire for User Interaction Satisfaction,[66] and these measures should also be correlated to efficacy. Moreover, future research should evaluate – using rigorous and, if possible, multicentric designs[22] – to what extent eMedRec is able to achieve the goal of improving patient safety and quality of care. A few such trials are currently ongoing.[7,10]

Outcome measures in future trials should include measures of adverse drug events and the number of unintentional medication discrepancies per patient. The latter measure has recently been endorsed by the United States National Quality Forum.[67] Such outcomes, together with selected process data, are worth considering in a core dataset. In addition, risks potentially introduced by eMedRec, such as over-reliance on electronic medication lists and technology-induced errors, will need to be evaluated.

Quality of reporting should be improved. The present work has shown that many reports lack adequate information on the characteristics of the tools and of their implementation. Context, the characteristics of the tools, and implementation features all have an impact on effectiveness. Future researchers should carefully describe each component, and particular attention should be paid to describing features that have been listed as essential for the successful implementation of eMedRec.[14,19]

Further research should investigate the quality of MedRec modules in EHRs and the incremental benefits of add-on MedRec software integrated with these EHRs. However, it should be noted that research on this topic might be hampered by a lack of scientifically rigorous data in peer-reviewed journals or patent databases, by a lack of information due to confidentiality considerations, and by difficulties in implementing direct comparisons, because no hospital is going to adopt more than one EHR at once. However, before/after studies by hospitals adopting different tools might be informative, as might be multihospital comparisons of adjusted discrepancy rates in institutions that use different EHRs.

Increasing patient engagement as another strategy for enhancing eMedRec efficiency[16] should be assessed by researchers. Patients can get involved, most often through patient portals, by providing their list of medications, by commenting on medication discrepancies between different lists, and by self-informing about nonadherence. For example, Siek et al.[17,68] developed the Colorado Care Tablet, a Personal Health Application that older adults with limited computing experience (ie., a population for which obtaining the best possible medication history is especially challenging)[17,37,40] could easily use.

Except for the APHID tool,[11,24] patient portal studies were excluded from the present review, due to the fact that portals were often not linked to an eMedRec tool or that description of the tool was lacking. From our viewpoint, patient portals remain an interesting way of involving patients and improving medication reconciliation,[69] and such data could inform developers of future eMedRec tools.

Limitations

This systematic review has several limitations. First, it is likely that we missed some existing eMedRec tools, because we limited our selection to English-language reports, because we cannot exclude publication bias, and because eMedRec tools developed in countries other than the United States may not have been patented. In addition, the translation of our research query in the Embase database generated difficulties. Indeed, "emtree" (Embase controlled vocabulary) did not contain any specific term for "medication reconciliation" (it was translated as "medication therapy management"). Despite this, our search strategy was comprehensive and not limited to published full-text papers. In addition, we did not restrict our selection to experimental designs. This was certainly appropriate given the objectives of this review, and the data from ongoing quality improvement studies and observations studies were valuable. Second, we had to exclude possibly interesting reports due to absent or incomplete data on the tools they described. Efforts were made to collect additional data from proceedings – some requests were successful but others were not. We did not attempt to collect additional data from authors of full-text papers with no data on the tool. Third, to be included, eMedRec tools had to support the entire MedRec process; this decision was taken for reasons of homogeneity and because we considered it to be an essential feature of eMedRec tools. However, several reports on tools that support some, but not all, steps of the MedRec process have generated some useful data. For example, Agrawal et al. developed an eMedRec system for use on admission to an acute care hospital.[39,70,71] Even though resolving discrepancies was not performed electronically, they reported a substantial reduction in medication errors, and the lessons learned from their experience were later used by many other research teams. More recently, Heyworth et al. found that enabling patients to conduct MedRec through a web portal was feasible during the transition from inpatient to outpatient care.[72]

CONCLUSION

The transition is under way from paper to eMedRec,[14] and the proportion of healthcare organizations using a fully electronic system for MedRec-related activities is expected to increase in the future. E-tools that support the entire MedRec process have been developed and evaluated. In addition to the functionalities of the tools, context and implementation must be carefully considered in order to maximize adherence and effectiveness, and should be more thoroughly reported. Evidence from rigorous studies is needed to evaluate the effect of eMedRec on the quality and safety of healthcare.

CONTRIBUTORS

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COMPETING INTERESTS

None.

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