Electronic medication reconciliation in hospitals: a systematic review and meta-analysis

Hongmei Wang, Long Meng, Jie Song, Jiadan Yang, Juan Li, Feng Qiu

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Department of Pharmacy, TheFirst Affiliated Hospital of Chongqing Medical University, Chongqing, China

Correspondence to

Dr Feng Qiu, Department of Pharmacy TheFirst Affiliated Hospital of Chongqing Medical University Chongqing China.; qiufeng.cn@gmail.com

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ABSTRACT

Objective Medication reconciliation (MedRec) is recognised as a multiprofessional process for the prevention of medication discrepancies. The goal of this study is to evaluate the available electronic medication reconciliation (eMedRec) tools and their effect on unintended discrepancies that occur in hospital institutions.

Method PubMed, EMBASE, the Cochrane Library, Web of Science, the ClinicalTrials.gov website and four other Chinese databases were searched for relevant studies starting from their inception through October 2017. Methodological quality was assessed using the nine standard criteria of Cochrane Effective Practice and Organisation of Care Review Group (EPoC) and meta-analysis was performed using RevMan5.3 software.

Results A total of 13 studies (three randomised controlled trials and 10 non-randomised controlled trials) were identified. Meta-analysis results demonstrated a reduced number of medications with unintended discrepancies (relative risk (RR)=1.85, 95% confidence interval (CI) 1.55 to 2.21), while no statistically significant differences were observed in the number of patients with unintended medication discrepancies (RR=2.74, 95% CI 0.59 to 12.73). Common discrepancies included medication omission, dose discrepancy, and frequency discrepancy. We found that the clinical impact of medication discrepancy was mild. A total of 12 electronic tools were reported and were mostly integrated into the hospital's information system. However, the usability, user adherence, and user satisfaction were found to lack sufficient evidence.

Conclusion eMedRec was shown to reduce the incidence of medication with unintended discrepancies and improve medication safety. However, the electronic tools are diversified and the effects on other outcomes still require a comprehensive evaluation.

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important interventions aimed at improving the safety of medication use in the 2017 National Patient Safety Goals by the Joint Commission.³ This uses a process to compare the medications taken by a patient (including name, dose, frequency, route and purpose) with newly ordered medications. This comparison addresses duplications, omissions, and the need to continue current medications.^{3,4} MedRec goals are described similarly, and it has been recognised by the Institute for Healthcare Improvement as a mechanism to reduce medication errors that could lead to adverse events and harm.⁵ As stated by the WHO High5s medication reconciliation SOP, this process can be carried out at admission, at internal transfer, and on discharge from the hospital.⁶

MedRec represents a matter of multidisciplinary care work, as it involves collaboration and teamwork among general practitioners, nurses, pharmacists and other healthcare professionals. Traditionally, the majority of hospitals use paper-based tools and systems for MedRec. According to some studies, this process was time consuming to complete with a pooled median (IQ) time of 50 (14, 50) minutes.⁷ With the development of electronic technology, an increasing number of healthcare organisations were found to use a completely electronic system for MedRec. Briefly, electronic medication reconciliation (eMedRec) was carried out by electronic tools or Health IT. In recent years, there have been numerous clinical trials related to eMedRec, with the number of studies regarding this continually increasing. What electronic tools can be used and what are the specific effects on clinical outcomes? This study aimed to systematically evaluate published clinical studies regarding the use of eMedRec in hospitals, with the ultimate goal of helping clinicians review and identify published reports systematically. In addition, this study also aimed to support evidence-based clinical decision-making.⁸

INTRODUCTION

Since the WHO Patient Safety Programme launched in 2004, patient safety has been recognised as a critical and serious global public health issue.¹ Specifically, safety surrounding medication represents a broad and complex area within patient safety, and was identified by WHO as the next Global Patient Safety Challenge.² Unsafe practices related to medication and medication errors are currently one of the leading causes of injury and healthcare associated harm around the world.

The goal of medication reconciliation (MedRec) is to identify and resolve medication discrepancies, and has been recognised as one of the most

METHODS

Search strategy

PubMed, EMBASE, the Cochrane Library, Web of Science, and four other Chinese Databases (Chinese Biomedical Literature Database (CBM), Chinese Scientific Journal Database (VIP), China National Knowledge Infrastructure (CNKI) and Wanfang database) were searched for relevant studies from their date of inception through October 2017. In addition, we also searched ClinicalTrials.gov. The search was limited to English language or Chinese, and the following relevant terms were used: 'medication reconciliation', 'medication discrepancies', 'medication errors', 'electronic' and 'computerised'.

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Figure 1 Flow diagram of the study selection process.

References cited in the included articles were studied in order to identify additional studies. Articles that did not have the full text available were not considered in this study.

Inclusion criteria and exclusion criteria

Studies were included if they met the following conditions: randomised controlled trials (RCTs), non-randomised controlled trials (NRCTs), controlled before–after (CBA) studies; medication reconciliation was carried out using electronic tools or Health IT in hospitals; the test group implemented eMedRec; and studies evaluated at least one outcome, such as medication discrepancies, electronic tools, potential adverse drug events (ADEs). Studies were excluded if MedRec was conducted using electronic tools with other interventions, and the data could not be extracted separately; they did not report the electronic tools used; and the studies were published as conference abstracts, books, letters or comments.

Study selection data extraction and quality assessment

Two investigators (WH and ML) carried out the assessments and screens independently, according to the title and abstract in the initial study selected. They then reviewed and retrieved the study based on the full-text copy of the articles. If an agreement could not be reached or there were any uncertainties, a third reviewer (SJ) would carry out a discussion with them in order to make a final decision. Two reviewers (WH and SJ) extracted the information using the previously prepared table for extraction and discussed and assessed the quality of the included studies using the nine standard criteria that were suggested by the Cochrane Effective Practice and Organisation of Care Review Group (EPOC).⁹

Data synthesis and analysis

Investigators carried out a meta-analysis of studies using the Review Manager (RevMan) Version 5.3, according to the Cochrane Handbook for Systematic Review of Interventions.¹⁰ In the case of dichotomous data, the relative risk (RR) was calculated for each trial with 95% confidence intervals (CIs). The data were then analysed by calculating the mean differences with their associated 95% CIs if they were continuous data. Heterogeneity was determined by calculating a χ^2 test of heterogeneity and an I^2 measure of inconsistency.¹¹ We used the random-effects model in cases where there was considerable heterogeneity

($P < 0.05$ or $I^2 > 50\%$) among the studies. Otherwise, a fixed-effects model was used. A sensitivity analysis was carried out by sequentially leaving one trial out and calculating the pooled RRs of the remaining studies.

RESULTS

Search results and study characteristics

We initially identified 1972 articles, with 352 duplicates automatically removed in Endnote X6. A total of 1566 articles were excluded following scanning of the title and/or abstract. The full text of the 54 remaining articles was then searched and read. It was determined that one study was not carried out in a hospital, nine studies included ineligible interventions, and 30 were further excluded due to ineligible studies design. Another article was also excluded due to the fact that the data could not be sufficiently extracted,¹² however we did include the final report from the same trial.¹³ In the end, a total of only 13 articles met our eligibility criteria. The article search and screening process are depicted in the flowchart (figure 1).

The characteristics of the included studies are depicted in online supplementary appendix tables A1. The publication year ranged from 2006 to 2017. A total of nine studies were carried out in the USA^{13–21} (69.2%), while the other three studies were performed in Spain^{22–24} and one in Canada.²⁵ Only three studies^{13 18 25} were RCTs (23.1%). The remainder of the studies had a pre–post study design. A total of five articles investigated hospital admission^{16 20 22–24} (38.5%), three articles investigated hospital discharge^{14 19 21} (23.1%), and others investigated both hospital admission and discharge. A total of 13 studies reported 12 types of electronic tools, with two studies found to use the same tools, referred to as APLICON application.^{22 23} The investigators were mostly nurses, pharmacists and physicians. The sample sizes in these studies ranged from 100 to 19 476 patients, or 3781 medications. The study length was found to range from 2 months to 32 months, with the exception of one study that did not report its study duration.¹⁹

Methodological quality of the included studies

We assessed the quality of all included studies using the EPOC risk of bias assessment tool.⁹ The results of the methodological quality of the included studies are depicted in online supplementary appendix tables A2. One RCT was not published, and only its final report was found. In this case, the methodology could not be judged sufficiently.¹³ Other RCTs were assessed as a low risk of bias in the nine items.^{18 25} Other trials were found to mostly have a high risk of bias in allocation concealment. As shown in online supplementary appendix tables A2, we found that the overall quality of studies was not enough high.

Outcomes of interventions

Medication discrepancies

A total of six studies^{14 17 21–24} were found to report the incidence of medications with unintended discrepancies over the total number of medications by eMedRec. The standard forest plots are depicted in figure 2. One study¹⁷ reported that their experiment was carried out in a surgical unit and medicine unit separately. Therefore, we analysed these data independently as two trials. Meta-analysis results of these studies demonstrated a reduction in the proportion of medications with unintended discrepancies (RR=1.85, 95%CI 1.55 to 2.21, $I^2=87\%$). After removal of the two studies,^{14 21} the results of the sensitivity analysis demonstrated a similar reduction between the eMedRec

Figure 2 Meta-analysis of the proportion of medications with unintended discrepancies.

group and the usual care group (RR=1.83, 95% CI 1.71 to 1.96, $I^2=0\%$).

A total of four studies^{16 19 23 24} reported the incidence of patients with unintended medication discrepancies. Standard forest plots are depicted in figure 3. Meta-analysis results of these studies demonstrated no significant differences in the proportion of patients with unintended medication discrepancies (RR=2.74, 95% CI 0.59 to 12.73, $I^2=98\%$). We carried out a sensitivity analysis according to the removal of one study;¹⁶ the results of the sensitivity analysis demonstrated similar results between the eMedRec group and usual care group (RR=1.42, 95% CI 0.92 to 2.19, $I^2=48\%$).

The categorisation of medication discrepancies

A total of seven studies^{14 16 17 19 22–24} reported on the types of medication discrepancies, including the drugs omitted, dose discrepancies, route of administration or frequency, therapeutic duplication, and treatment started with an absence of a clinical explanation. We carried out the following meta-analysis by extracting information regarding the number of medications with unintended discrepancies and the total number of medications.

First, we found that the omission of medicine was the most frequent medication discrepancy. The meta-analysis of six studies^{16 17 19 22–24} showed that of the total number of medications administered, the proportion was decreased significantly in the intervention group (RR=4.40, 95% CI 1.70 to 11.38, $I^2=95\%$). The standard forest plots are depicted in figure 4. After moving the data of two studies,^{16 17} sensitivity analysis results demonstrated no significant reduction (RR=2.02, 95% CI 0.91 to 4.50, $I^2=89\%$). Second, we found that dose discrepancy was another

one of the most common types of medication discrepancy. The results of four studies^{14 16 19 24} demonstrated no significant difference between the groups (RR=3.32, 95% CI 0.71 to 14.54, $I^2=92\%$). A third type of medication discrepancy identified was frequency. The results of four studies^{14 16 19 24} demonstrated no significant difference between the two groups (RR=3.02, 95% CI 0.52 to 17.54, $I^2=90\%$). Finally, three studies^{14 23 24} reported the incidence of therapeutic duplication, and there was no significant difference identified before and after the experiment in the meta-analysis (RR=2.49, 95% CI 1.40 to 4.43, $I^2=0\%$). The results of two studies^{23 24} showed the treatments that were started with no clinical explanation between the two groups had no significant difference (RR=3.17, 95% CI 0.42 to 24.01, $I^2=1\%$).

Clinical impact of medication discrepancy

A total of six studies^{15 18 20 22–24} reported harm caused as a result of medication discrepancy. Category C errors were identified to be the most common errors. Kamer *et al*¹⁵ reported two category B errors and one category C error in pre-implementation; and three category B errors and one category C error in pre-implementation. Gimenez Manzorro *et al*²⁴ identified category C errors (79.2%), category D errors (13.6%), and category E errors (7.1%) in the total study sample. Gimenez Manzorro *et al*²² observed a reduction in the number of type C errors in the phase following intervention, 48/1958 (2.4%), compared with the phase prior to the use of eMedRec, 96/1823 (5.3%). Only the study carried out by Zoni *et al*²³ observed no harm caused by unintended discrepancies. Schnipper *et al*¹⁸ reported that the mean number of medication discrepancies per patients decreased

Figure 3 Meta-analysis of the proportion of patients with unintended medication discrepancies.

Figure 4 Meta-analysis of the proportion of omission errors compared with the total number of medications.

in the eMedRec group (1.05 vs 1.44). Hron *et al*²⁰ observed that a 42% non-intercepted potential ADEs, 22% mild ADEs and two errors (1%) were moderate ADEs, and no major or catastrophic ADEs related to medication reconciliation were identified.

eMedRec tool

A total of 13 studies reported 12 electronic tools, and the description of eMedRec tools are summarised in table 1. Six studies^{14–18, 25} reported that their tools were integrated into the workflow. All of the tools, with the exception of the one study,¹⁴ linked to other electronic systems, such as computerised physician order-entry system (CPOE), electronic health record (EHR), electronic medical record (EMR), and clinical

patient care system (CPCS). However, none of these tools were commercially available on the market, and only a few studies reported their usability. Only one study described user satisfaction. From this user satisfaction survey, it was found that patients in the eMedRec group had a higher level of agreement on the eMedRec, as well as a greater understanding of the medications they were to take following discharge from the hospital.¹⁵ However, in the case of healthcare providers, they did not report any positive response after using eMedRec.

A total of five studies evaluated user adherence. Poor physician compliance (21.0%, 50/238) was found in a study carried out by Poole *et al*.¹⁴ Hron *et al*²⁰ reported that the adoption of the eMedRec tool increased to 83.8% in the post-intervention

Table 1 Description of eMedRec tools

Author, year	Country	eMedRec tool	Tool			Evaluation		
			Integrated into the workflow?	Linked to other electronic systems?	Availability of the tools commercially?	Usability evaluated?	Evaluation of users' adherence?	Evaluation of users' satisfaction?
Poole 2006 ¹⁴	USA	Physician Discharge Medication Worksheet (PDMW)	yes	NR	NR	NR	yes	NR
Kramer 2007 ¹⁵	USA	An electronic system for medication reconciliation based on CPCS	yes	CPCS	NR	NR	NR	yes
Agrawal 2009 ¹⁶	USA	MedRec application (MedRec system integrated in the EHR)	yes	EHR	NR	NR	yes	NR
Murphy 2009 ¹⁷	USA	EMR medication document tool	yes	EMR	NR	NR	NR	NR
Schnipper 2009 ¹⁸	USA	Preadmission Medication List (PAML) Builder	yes	CPOE	NR	NR	yes	NR
Gimenez Manzorro 2011 ²²	Spain	APLICON application	NR	CPOE	NR	NR	NR	NR
Zoni 2012 ²³	Spain	APLICON application	NR	CPOE	NR	NR	NR	NR
Weiner 2012 ¹³	USA	eMedRec system with an electronic prescribing system	NR	CPOE	NR	NR	NR	NR
Allison 2015 ¹⁹	USA	Electronic discharge medication reconciliation tool (EDMRT)	NR	CPOE	NR	NR	NR	NR
Gimenez Manzorro 2015 ²⁴	Spain	Electronic reconciliation tool	NR	CPOE	NR	NR	NR	NR
Hron 2015 ²⁰	USA	Electronic medication reconciliation tool within the EHR	NR	EHR	NR	NR	yes	NR
Smith 2016 ²¹	USA	EMR-based discharge medication reconciliation tool	NR	EMR	NR	NR	NR	NR
Tamblyn 2017 ²⁵	Canada	RightRx application	yes	Hospital pharmacy system (GE Centricity)	NR	NR	yes	NR

CPCS, clinical patient care system; CPOE, computerised physician order-entry system; EHR, electronic health record; EMR, electronic medical record.

period. Schnipper *et al*¹⁸ also found that full use of the Preadmission Medication List (PAML) Builder was not achieved, with only 46.3% (75/162) of patients having completed the PAML within 24 hours of admission and 74.7% (121/162) were discharged. Another study reported more positive results, demonstrating that use of the electric tool improved compliance with the MedRec process from 34% to 98%–100%.¹⁶ The same result was also reported by Tamblyn *et al*²⁵ the overall medication reconciliation completion rate was 88.1% (1242/1410) in the software intervention units compared with 46.3% (698/1506) in the control units.

DISCUSSION

This systematic review evaluated both the impact of eMedRec and its electronic tools, and our study demonstrated that eMedRec provided a positive effect on the proportion of medications with unintended discrepancies. However, no significant difference was observed on the proportion of patients with unintended medication discrepancies. We also identified the most common type of discrepancy to be medication omission, a result confirmed in a recent study.²⁶ Although eMedRec was shown to significantly reduce omission errors and therapeutic duplication over the total number of medications, no statistical significant changes on other types of medication discrepancies were observed. We also found other types of medication discrepancy in the included studies, including different drugs, different routes of administration, interactions, etc. However, we were unable to analyse these data using RevMan software, as the data provided were insufficient and were reported to be diverse. Another critical reason that these data could not be analysed was that the methods of classification for both unintentional and intentional discrepancies were generally empirically based, indistinct and unstructured.²⁷ This was especially true in the case of unintentional discrepancies. Therefore, we desire implementation of comprehensive or authoritative classification criteria regarding medication unintentional discrepancies.

From the included study, the results of patient safety evaluations were mostly descriptive data and were reported variously; the majority of the studies used the categories of severity assessment by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP),²⁸ with the exception of one study¹⁵ that used the article of Nickerson *et al* as a reference.²⁹ Currently, there exists no standard to evaluate the severity of unintentional medication discrepancies. Therefore, we are unable to perform a meta-analysis. We found that serious harm caused by unintended discrepancies was seldom reported. The most common errors were found to be mild or category C errors, meaning that the error reached the patient but caused no harm. However in the previous study, it was reported that approximately 59.9% (121/202) of clinically significant medication discrepancies possessed the potential to threaten patient safety, but this study did not use eMarRec tools.³⁰ Therefore, it remains uncertain whether eMedRec tools have the ability to increase patient safety.

To the best of our knowledge, the previous reviews²⁶ assessed only the effect of eMedRec, but did not evaluate the eMedRec tools. In our study, we have identified 12 eMedRec tools from a total of 13 articles. While most of the included studies did not report the detailed information regarding the tools, it is clear that we found the eMedRec tools to be almost integrated into the information technology that was commonly used in hospitals such as CPOE, CPCS and EMR. These systems could not detect any unintentional medication errors when they worked alone,

however they could help to build an accurate medication list. In regard to other aspects, the MedRec process is a multidisciplinary task that costs time, and eMedRec tools would save time and reduce the workload for healthcare institutions when linked to health information technology systems. It has been proven that eMedRec is preferable to a paper-based process in organisations that have an EHR and CPOE.³¹ In addition, it was found that implementation of the eMedRec tool had a significant impact on improving compliance.^{31–32} Meanwhile, one study demonstrated that increased participation of patients and clerical staff in the generation of medication lists can improve the MedRec process.³³ Whether the workflow can function to facilitate or increase the compliance of MedRec remains unknown, due to a lack of more evidence.

Currently, the results of research regarding electronic tools are not optimistic. Several studies have reported how eMedRec performed in the process of standardisation and workflow, and the electronic tools were mostly not commercially available. In addition, trials seldom explored the usability of eMedRec tools, user adherence or user satisfaction. While a total of 12 different tools were included in our study, the results of our study reflected only their usage. We currently do not know whether these tools are suitable for other countries. Thus, the development of electronic tools that are commercially available, easy to use, and offer high compliance is expected by all.

Study limitations

In our study, there exist some limitations. First, we included only RCTs and NRCTs. Therefore, we may have missed several studies which described eMedRec tools. In regards to the language, we included only those studies in English or Chinese, however no Chinese articles were included. In addition, the number of studies included in the meta-analysis was small. Therefore, we did not generate funnel plots, thereby increasing the risk of reported bias. Second, the quality of the studies included was not of high enough calibre, and the majority of studies were not RCTs. As a result, this may lower the quality of our evidence reported. Third, there was heterogeneity among studies in the meta-analysis of medication discrepancies. Interventions, population characteristics, study duration and methods for measuring outcomes are possible sources of heterogeneity. However, for some outcomes, we did not perform sufficient analysis. For example, among the included studies there was a lack of trials that reported the same tools, or explored the relationship between medication discrepancies and the characteristics of patients, including age, sex, disease or medications, which resulted in no subgroup analysis. Accordingly, more high-quality studies and an assessment of a greater number of outcomes will be required in the future.

CONCLUSION

Medication reconciliation based on electronic tools was demonstrated to have a positive effect on the proportion of medications with unintended discrepancies. Although the use of eMedRec was found to reduce the omission error over the total number of medications and therapeutic duplications, no significant changes in regard to other types of medication discrepancy were identified. Because only a few of the studies evaluated the usability of eMedRec tools, user adherence or satisfaction, and due to the fact that eMedRec tools are not commercially available, a greater number of studies generating high-quality evidence are needed.

Contributors Draft the protocol: WH, QF, ML, SJ, LJ, YJ. Develop and run the search strategy: WH, ML, SJ. Obtain copies of studies: WH, SJ, LJ. Select which studies to include: WH, ML, YJ. Extract data from studies: WH, ML, SJ. Enter data into RevMan:

WH, SJ, LJ. Carry out the analysis: WH, ML, SJ, LJ, YJ. Interpret the analysis: WH, ML, YJ. Draft the final review: WH, ML, SJ, LJ, YJ, QF.

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