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## Automated communication tools and computer-based medication reconciliation to decrease hospital discharge medication errors

**Kenneth J. Smith, MD, MS<sup>1</sup>, Steven M. Handler, MD, PhD<sup>2</sup>, Wishwa N. Kapoor, MD, MPH<sup>1</sup>, G. Daniel Martich, MD<sup>3</sup>, Vivek K. Reddy, MD<sup>4</sup>, and Sunday Clark, ScD, MPH<sup>5</sup>**

<sup>1</sup>Division of General Internal Medicine, Department of Medicine, University of Pittsburgh, Pittsburgh, PA

<sup>2</sup>Department of Biomedical Informatics, School of Medicine, and Division of Geriatric Medicine, Department of Medicine, University of Pittsburgh, Pittsburgh, PA

<sup>3</sup>Chief Medical Information Officer, UPMC, and Department of Critical Care Medicine, School of Medicine, University of Pittsburgh, Pittsburgh, PA

<sup>4</sup>Chief Medical Information Officer, Hospital Services, UPMC, and Department of Neurology, University of Pittsburgh, Pittsburgh, PA

<sup>5</sup>Division of Emergency Medicine, Department of Medicine and Department of Public Health, Weill Cornell Medical College, New York, NY

### Abstract

In this study, we sought to determine, in hospitalized patients, the effects of automated PCP communication and patient safety tools, including computerized discharge medication reconciliation, on discharge medication errors and post-hospitalization patient outcomes, using a pre-post quasi-experimental study design, in hospitalized medical patients with 2 comorbidities and 5 chronic medications at a single center. The primary outcome was discharge medication errors, compared before and after rollout of those tools. Secondary outcomes were 30-day rehospitalization, emergency department visit, and PCP follow-up visit rates. We found that discharge medication errors were lower post-intervention (OR 0.57, 95% CI 0.44–0.74,  $p < 0.001$ ). Clinically important errors, with the potential for serious or life-threatening harm, and 30-day patient outcomes were not significantly different between study periods. Thus, automated health system-based communication and patient safety tools, including computerized discharge medication reconciliation, decreased hospital discharge medication errors in medically complex patients.

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Hospitalized patients in the US are increasingly being cared for by physicians other than their primary care physicians (PCPs).<sup>1</sup> In 2010, more than 80% of US hospitals with 200

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**Corresponding author:** Kenneth J. Smith, MD, MS, 200 Meyran Ave., Suite 200, Pittsburgh PA 15232, 412 647-4794 fax 412 246-6954, smithkj2@upmc.edu.

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beds had hospitalist programs.<sup>2</sup> As a result, the importance of communication between hospital providers and PCPs to prevent medical errors and improve quality of care has come to the forefront.<sup>3–6</sup> Hospital systems are, for the most part, not optimized to provide efficient transfer of this vital information, and communication between physicians caring for hospitalized patients and PCPs is often suboptimal.<sup>7–9</sup>

For patients with complex medical problems, the hospital discharge period is particularly prone to errors.<sup>5</sup> Medications may have been discontinued, added, or had dosing changes during a hospitalization, frequently leading to errors. Medical errors are common in the early post discharge period,<sup>10</sup> and adverse events occur in about 20% of patients post discharge, most often due to medications.<sup>11,12</sup> Medication errors and adverse drug events (ADEs) are frequently caused by hospital system factors,<sup>13</sup> such as ineffective communication between caregivers.<sup>11</sup> Almost half of discharged patients have unexplained medication discrepancies, heightening ADE risk.<sup>14</sup> Medication reconciliation is a Joint Commission National Patient Safety Goal and a core measure of Stage 2 meaningful use.<sup>15</sup> However, hospitals and electronic medical record (EMR) vendors have struggled to meet this mandate.<sup>16,17</sup>

Prior research has studied interventions to decrease medication errors at hospital discharge and improve patient outcomes.<sup>18</sup> Some interventions used medication reconciliation performed by pharmacists, with medication errors being variably affected by these interventions.<sup>19,20</sup> Computerized medication reconciliation tools have been developed<sup>21</sup> and have shown promise as a means to decrease medication errors, but effects on patient outcomes are unclear.<sup>22,23</sup> Here we examine a health care system's implementation of a broader set of automated PCP communication tools, including computerized medication reconciliation, and its impact on discharge medication errors.

## Methods

We performed a pre-post quasi-experimental study of a series of system-wide automated communication and patient safety tools within the University of Pittsburgh Medical Center (UPMC) system, which in 2010 operated 20 hospitals throughout Western Pennsylvania. Data were collected for patients hospitalized at UPMC Presbyterian, UPMC's major academic hospital.

The University of Pittsburgh IRB approved a waiver of informed consent/HIPAA authorization to access, record, and use protected patient health information/patient medical record information. This study is registered at [ClinicalTrials.gov](https://clinicaltrials.gov), Identifier: NCT01397253.

The pre-intervention period for this study was April 1, 2009 through October 7, 2010. The end date was chosen based on the first of the new automated PCP communication initiatives, rolled out October 8, 2010. Assisted by an expert PCP panel, using the modified Delphi technique to seek consensus on information items PCPs want to receive,<sup>24</sup> other initiatives were sequentially rolled out to improve notifications about admission, critical illness occurrence, test results, and discharge communication (see Box). The UPMC Office of Physician Relations sent notifications by secure email or fax, using the PCPs' preferred method. The Office of Physician Relations maintained addresses, and phone numbers to

ensure timely notification delivery, while managing and correcting any process failures. These efforts culminated in a mandatory EMR-based discharge medication reconciliation procedure, with reports given to patients and sent to PCPs. This procedure, implemented in Cerner PowerChart, UPMC's inpatient EMR, was launched on August 22, 2011; this began the post-intervention period, which ended December 31, 2012. At hospital discharge, physicians used this tool to reconcile discharge medications against medication histories obtained on hospital admission by hospital personnel; use was required to order discharge medications and discharge patients. In the pre-intervention period, a paper-based non-mandatory discharge medication reconciliation process was in place, similarly reconciling against medication histories obtained by hospital personnel; its effectiveness was unclear.

Patients were included if: admitted to General Medicine, Geriatrics, or Cardiology inpatient services; 18 years of age; discharged home; medically complex (2 comorbid conditions present, defined using the Elixhauser comorbidity system<sup>25</sup>); prescribed 5 preadmission medications (a measure of polypharmacy); and had outpatient care provided by PCPs who 1) use the UPMC Epic ambulatory care EMR and 2) admitted 5 patients to UPMC Presbyterian in the year preceding the study. The Epic ambulatory EMR is used by approximately 90% of UPMC outpatient providers. Patients were excluded if admitted to critical care units, admitted from skilled nursing facilities, diagnosed with dementia, or were organ transplant recipients; exclusions were based on the expectation that study patients would be admitted from and discharged to a community setting where they would resume care with their PCP. All medically complex patients identified and meeting inclusion/exclusion criteria were included in analyses.

Medication errors were identified using a 2-stage process.<sup>26,27</sup> For the purposes of the study, this process was performed retrospectively after a patient's hospital discharge, and thus was entirely separate from procedures performed during the hospitalization by hospital personnel during all phases of our study. In the first stage of the study-based process, trained research personnel created a case summary of each patient's medications, which included preadmission medications, medications prior to discharge, and discharge medications. This case medication summary was created by examining ambulatory EMR data on a patient's current medications at the last PCP encounter before hospitalization. This retrospectively constructed list, intended to be a "gold standard" representation of pre-hospital medication usage, was not connected to the medication history obtained by hospital personnel at the time of admission. Hospital medications and discharge medications were included in the study-based medication case summary using hospital EMR data post discharge. Discharge medications were those listed, after medication reconciliation, in discharge medication instructions given to the patient and sent to the PCP. Discrepancies in medication regimens were identified by comparing the preadmission medication list, hospital medications, and discharge medications. Any differences between the study-based preadmission medication case summary and discharge medications were considered medication variances. Hospital personnel, when obtaining the medication history, had access to the outpatient EMR throughout all study periods.

During the second stage of the study-based medication error identification process, 2 hospital-based clinical pharmacists independently reviewed those study-based medication

variance summaries, using previously described methods.<sup>27</sup> Both pharmacists had previous experience and concurrent activity in clinical medication review, and received refresher training in error classification. They reviewed the EMR to identify the need for changes from the patient's preadmission medication case record. Medication variances deemed medically necessary were not considered medication errors. Variances not considered changes required by the patient's clinical status were classified as medication errors. They then independently classified medication errors, via the schema of Pippens et al.,<sup>27</sup> as clinically important if there was the potential to cause: death, permanent or temporary disability, prolonged hospital stay, readmission, or additional treatment or monitoring to protect the patient from harm; by this schema,<sup>27</sup> these were serious or life-threatening potential ADEs. All disagreements between pharmacists were resolved by consensus during periodic face-to-face meetings, supplemented by telephone and electronic communication. The pharmacists could not be blinded, due to their use of the entire EMR in their reviews and the time-based nature of the intervention. Data for secondary outcomes (30-day readmission, emergency department visits, and follow-up PCP visits) were obtained through EMR review. Patients with >1 hospitalization during a study period were eligible for inclusion only during their first hospitalization, but could be included once each during the pre- and post-intervention periods.

All comparisons were performed using Kruskal-Wallis and chi-square tests. To control for potential confounders, multivariable logistic regression was performed. Factors were included in the multivariable mixed effects model if they were significantly associated with the outcome variable (unintended medication variances) at  $P < 0.20$  or considered potentially clinically significant. A  $P < 0.20$  was chosen because more traditional levels (e.g.,  $P < 0.05$ ), can, in multivariable models, fail to identify: 1) variables known to be important or 2) collections of variables that, considered together, are significant predictors when they are not significant individually.<sup>28</sup> Because they could contribute to both study periods and because of multiple medications per individual, patients were included in the mixed effects model as a random effect and individual patient characteristics were included as fixed effects. Pre-hoc power and sample size calculations showed that detection of a 10% absolute reduction in discharge medication errors (primary outcome) from an estimated baseline of 41% at  $\alpha = 0.05$  and 90% power required enrollment of 381 participants during each period ( $n = 762$  over the entire study). We planned enrollment of 500 patients in each period to increase power to detect differences in 30-day rehospitalization, emergency department visits and PCP follow-up visits (secondary outcomes), with 80% power to detect 6% absolute reductions.

Changes in clinical responsibilities prevented all cases from being reviewed by both pharmacists. As a result, the primary analysis includes only cases reviewed by both pharmacists to ensure consensus regarding medication variances. We also performed a sensitivity analysis including all cases, whether reviewed by one or both pharmacists. In addition, we performed a post-hoc secondary analysis examining possible associations of gender, race, and hospital length of stay with medication errors.

## Results

Data on 835 patient hospitalizations were obtained, 443 pre-intervention and 392 post-intervention. Of these, 560 (67%) had discharge medication variances reviewed by both pharmacists (317 pre-intervention, 243 post-intervention); these patients are included in the primary analysis, the remainder are included in a sensitivity analysis. Twenty-eight patients were in both pre and post cohorts. Age, gender, and race did not differ between study periods (Table 1). Post-intervention patients were significantly more likely to have employer/commercial insurance. Modified Elixhauser comorbidity index scores<sup>29</sup> and medications per patient were slightly lower post-intervention.

Fewer medication errors occurred during the post-intervention period. Clinically important medication errors did not differ between study periods. While there was a small but statistically significant decrease in PCP follow-up visits post-intervention, no differences were observed in hospital readmissions or ED visits.

Differences in medication errors remained statistically significant on multivariable analysis adjusting for age, sex, insurance, comorbidity, and number of medications (Table 2).

A sensitivity analysis, including cases only reviewed by a single pharmacist (totaling 835 hospitalizations, 443 pre-intervention and 392 post-intervention), showed results not materially different from the primary analysis, with the fully adjusted multivariable mixed effects model showing a reduction in medication errors post-intervention (OR 0.52, 95% CI 0.42–0.66,  $p < 0.001$ ). No significant differences were seen, after adjustment, in clinically significant medication errors or in 30-day patient outcomes.

In post-hoc secondary analyses to assess associations between medication errors and gender, race, and hospital length of stay, race was not associated with medication errors (data not shown). However, females were more likely to have medication errors (OR 1.40; 95% CI 1.11–1.75) after adjustment for age, insurance, comorbidity, and number of medications, and longer hospital stays were associated with fewer discharge medication errors (1<sup>st</sup> quartile: reference; 2<sup>nd</sup> quartile: OR 0.91, 95% CI 0.68–1.21; 3<sup>rd</sup> quartile: OR 0.56, 95% CI 0.41–0.76; 4<sup>th</sup> quartile: OR 0.60, 95% CI 0.45–0.82) in the fully adjusted model. Stratifying by study period did not materially change results (data not shown).

## Discussion

In this study, we examined the impact of automated health system-based interventions on patient care quality and safety, in the context of a PCP's patient being admitted to the hospital, cared for by another physician, and discharged back to the PCP's care. Statistically significant decreases in medication errors were seen when comparing pre- and post-intervention periods. Clinically significant medication errors with potential for serious or life-threatening consequences were rare and no different between study periods. Thirty-day patient care outcomes in rehospitalization and emergency department visits were not significantly different between study periods after adjustment.

The intervention included automated communications to notify PCPs of their patients' admission, discharge, and critical care transfers during a hospitalization and receive, at discharge, important information on follow-up care. This information includes studies whose results were pending and reports from a mandatory computerized medication reconciliation process. Unfortunately, we cannot measure individual intervention component effectiveness. Since our study did not measure the effects of automated hospital communications on hospital/PCP interactions, it could be argued that the EMR-based mandatory discharge medication reconciliation was the key component in decreasing medication errors, with PCP communication unlikely to affect this outcome. If so, demonstration that software-based medication reconciliation successfully reduced medication errors is still a valuable finding, and consistent with prior studies.<sup>22,23</sup> A conference convened to discuss challenges facing medication reconciliation, including myriad tracking systems, unclear responsibilities, and systems development needs, has made recommendations to help resolve them.<sup>17</sup> On the other hand, communication between hospitalists and PCPs is a recent focus of research and guidelines, with hopes that electronic communication tools will improve patient care quality and outcomes,<sup>4-6,30</sup> and lead to information exchange between both parties, rather than passive information transfer from hospital to PCP.<sup>31</sup> In theory, highly developed two-way electronic communication systems between hospitals and PCPs, with access to EMR data and direct communication links to hospital caregivers, could allow PCPs the option to participate more directly in their patients' hospital care at a distance, providing virtual continuity of care through electronic means and, through this interaction, avoiding transition of care miscommunications that could lead to medical errors.

In this study, comparisons were made between preadmission medication lists retrospectively created by research personnel based on ambulatory EMR data and discharge medications. Thus, the effectiveness of entire hospital medication transition reconciliation and prescribing process was tested *en bloc*, noting uncorrected medication errors occurring from preadmission medications onward through the hospitalization, based on discrepancies between lists. Ambulatory EMR use to construct prehospitalization medication lists could be criticized if long intervals between PCP visits and hospitalizations were seen, with new medications possibly added by non-PCP physicians in the interim but not noted in the EMR. However, our medication summaries were identically obtained throughout all study periods, thus differences attributable to this effect should cancel out between pre- and post-intervention periods. Finally our study-based reviewing pharmacists were not blinded, a potential limitation, due to their needing access to the entire EMR for their determinations.

We did not find differences in clinically important medication errors or in patient outcomes. Interestingly, our clinically important medication error rates were lower than typically reported.<sup>27</sup> It is not clear why. We used a common definition for errors,<sup>27</sup> and well-described format for finding them.<sup>26,27</sup> Our study-based medication case record was obtained independently from the clinical medication history. Two trained clinical pharmacists examined each case record and, for the primary analysis, reached consensus on medication error classification. In our institution, a paper-based medication reconciliation process had been in place before our intervention, possibly diluting its effect. More recent studies found serious potential ADE rates at hospital discharge from 0.01 to 0.21 per patient;<sup>32</sup> we found 0.03 and 0.05 per patient in pre- and post-intervention respectively. In addition, we could

have underestimated 30-day outcomes if visits occurred at non-UPMC facilities, since outcomes were ascertained using UPMC EMR data, a study limitation. However, study subjects were patients of PCPs who use the UPMC EMR, likely mitigating this effect.

In post-hoc secondary analyses, we found associations of errors with female gender and hospital length of stay. Greater medication error risk in women has been reported previously;<sup>33</sup> its mechanism is unclear. Medication error risk decreased with longer hospital length of stay, a finding not described elsewhere. Although requiring confirmation, it raises several possibilities. Medication errors are commonly made at hospital admission;<sup>32</sup> longer hospitalizations may provide more opportunities for error correction. Patients with shorter stays may be perceived as less sick and less vigilance could result. Finally, patients with in-hospital ADEs have longer lengths of stay.<sup>34</sup> ADEs could trigger greater attention to medications and fewer errors at discharge.

There are limitations in quasi-experimental study designs.<sup>35</sup> A non-randomized study could insufficiently control for important confounding variables. We controlled for variables where significant differences were found between study groups, but unmeasured confounders could still affect results. Secular trends toward decreasing discharge medication errors could also explain our results. However, a less than 11 month gap between study periods makes this less likely. Introduction of the intervention represented a historical event that could have changed physician attitudes and affected results. On the other hand, randomized trials of medical informatics interventions are often difficult to perform within a single facility, due to barriers to selective rollout of interventions.<sup>35</sup> Contamination effects, where personnel learning a new intervention could apply it to all patients regardless of randomized group, could also occur.

Thus, a multicenter randomized trial of our automated tools would need to be performed to definitively demonstrate benefit. A multicenter randomized trial at 6 US hospitals of best practices to improve medication reconciliation is ongoing. This effort, the Multicenter Medication Reconciliation Quality Improvement Study (MARQUIS), will assess multiple interventions, including medication reconciliation software, to specifically address obtaining of a “best medication history” from hospitalized patients and using multiple processes to ensure that all necessary medications are taken post discharge.<sup>32</sup>

In conclusion, implementation of automated health system-based tools, including computerized discharge medication reconciliation, decreased hospital discharge medication errors in medically complex patients. Definitive assessment of these tools will await future multicenter trials.

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**Box****Intervention elements**

Hospital admission notifications to PCPs with contacts for communication

PCP notification of patient transfer to critical care units

Mandatory computer-assisted discharge medication reconciliation

PCP notifications at a patient's hospital discharge

Current problem list

Advance directive information

Vaccination history

Reconciled medication list

Major tests and procedures

Test results pending

Planned follow-up

Patient discharge instructions

Patient information material/education received

Hospital contacts for communication

Discharge summary

**Table 1**

## Characteristics and Outcomes of Participants by Study Period

	Pre-intervention n=317	Post-intervention n=243	P value
<i>Demographic Characteristics</i>			
Age (years), median (IQR)	63 (53 – 76)	63 (54 – 73)	0.43
Sex (%)			0.20
Male	139 (44)	93 (38)	
Female	178 (56)	150 (62)	
Race (%)			0.44
White	216 (68)	151 (62)	
Black	96 (30)	86 (35)	
Native American/Alaskan Native	1 (0.3)	1 (0.4)	
Asian	3 (1)	4 (2)	
Hispanic	1 (0.3)	0 (0)	
Missing	0 (0)	1 (0.4)	
Insurance (%)			<0.001
Private	96 (30)	193 (79)	
Public	215 (68)	50 (21)	
Uninsured	4 (1)	0 (0)	
No documentation	2 (1)	0 (0)	
<i>Clinical Characteristics</i>			
Number of comorbidities (%)			<0.001
0	9 (3)	4 (2)	
1	62 (20)	75 (31)	
2	118 (37)	106 (44)	
3	83 (26)	47 (19)	
4	32 (10)	10 (4)	
5	12 (4)	1 (0.4)	
6	1 (0.3)	0 (0)	
Modified Elixhauser comorbidity index, median (IQR)	5 (3 – 11)	3 (0 – 5)	<0.001
Hospital length of stay (days), median (IQR)	3 (2 – 4)	2 (2 – 4)	0.54
Number of medications, median (IQR)	11 (8 – 15)	8 (6 – 10)	<0.001
Number of medications (%)			<0.001
5–9	107 (34)	165 (68)	
10–14	126 (40)	61 (25)	
15–19	62 (20)	14 (6)	
20–24	15 (5)	3 (1)	
25–29	6 (2)	0 (0)	
30	1 (0.3)	0 (0)	
<i>Medication Variance</i>			
Medication variance (%)			<0.001

	<b>Pre-intervention n=317</b>	<b>Post-intervention n=243</b>	<b>P value</b>
None	1,836 (53)	1,650 (58)	
Medically indicated variance	1,009 (29)	814 (29)	
Medication error	645 (18)	359 (13)	
Clinically important medication error	9 (1.4)	11 (3.1)	0.10
<i>30-day Follow-up</i>			
Readmission (%)	58 (18)	41 (17)	0.74
Emergency department visit (%)	81 (26)	49 (20)	0.16
Attended PCP follow-up appointment (%)	148 (47)	109 (45)	0.04
Died (%)	0 (0)	0 (0)	–

IQR denotes interquartile range; PCP primary care provider.

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**Table 2**

Multivariable Mixed Effects Model of Intervention Effects on Unintended Medication Variances (Medication Errors)

	<b>Odds ratio</b>	<b>95% confidence interval</b>	<b>P value</b>
Unadjusted	0.63	0.51 – 0.77	<0.001
Adjusted for age, sex, and insurance	0.54	0.43 – 0.69	<0.001
Adjusted for age, sex, insurance, and comorbidity score	0.52	0.41 – 0.67	<0.001
Adjusted for age, sex, insurance, comorbidity score, and number of medications	0.57	0.44 – 0.74	<0.001

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