Effect of an Electronic Medication Reconciliation Application and Process Redesign on Potential Adverse Drug Events

A Cluster-Randomized Trial

Jeffrey L. Schnipper, MD, MPH; Claus Hamann, MD, MS; Chima D. Ndumele, MPH; Catherine L. Liang, MPH; Marcy G. Carty, MD, MPH; Andrew S. Karson, MD, MPH; Ishir Bhan, MD; Christopher M. Coley, MD; Eric Poon, MD, MPH; Alexander Turchin, MD, MS; Stephanie A. Labonville, PharmD, BCPS; Ellen K. Diedrichsen, PharmD; Stuart Lipsitz, ScD; Carol A. Broverman, PhD; Patricia McCarthy, PA, MHA; Tejal K. Gandhi, MD, MPH

Background: Medication reconciliation at transitions in care is a national patient safety goal, but its effects on important patient outcomes require further evaluation. We sought to measure the impact of an information technology–based medication reconciliation intervention on medication discrepancies with potential for harm (potential adverse drug events [PADEs]).

Methods: We performed a controlled trial, randomized by medical team, on general medical inpatient units at 2 academic hospitals from May to June 2006. We enrolled 322 patients admitted to 14 medical teams, for whom a medication history could be obtained before discharge. The intervention was a computerized medication reconciliation tool and process redesign involving physicians, nurses, and pharmacists. The main outcome was unintentional discrepancies between preadmission medications and admission or discharge medications that had potential for harm (PADEs).

Results: Among 160 control patients, there were 230 PADEs (1.44 per patient), while among 162 intervention patients there were 170 PADEs (1.05 per patient) (adjusted relative risk [ARR], 0.72; 95% confidence interval [CI], 0.52-0.99). A significant benefit was found at hospital 1 (ARR, 0.60; 95% CI, 0.38-0.97) but not at hospital 2 (ARR, 0.87; 95% CI, 0.57-1.32) (P=.32 for test of effect modification). Hospitals differed in the extent of integration of the medication reconciliation tool into computerized provider order entry applications at discharge.

Conclusions: A computerized medication reconciliation tool and process redesign were associated with a decrease in unintentional medication discrepancies with potential for patient harm. Software integration issues are likely important for successful implementation of computerized medication reconciliation tools.

Trial Registration: clinicaltrials.gov Identifier: NCT00296426

Arch Intern Med. 2009;169(8):771-780
tient outcomes or define the best ways to implement these processes or identify the patients most likely to benefit. We sought to determine the effects of a redesigned process for medication reconciliation, supported by information technology (IT), on potential ADEs (PADEs). We hypothesized that our intervention would decrease PADEs in all patients and that patients at high risk for medication discrepancies would benefit most.

**METHODS**

**STUDY DESIGN, SETTING, AND PARTICIPANTS**

The Partners Medication Reconciliation Study was a cluster-randomized controlled trial conducted from May 1 through June 20, 2006, at 2 large academic hospitals in Boston, Massachusetts. The design of this study has been described.16 Eligible patients were admitted to one of several general medicine teams and floors of each hospital, according to a rotating call cycle. Each team (6 at hospital 1 and 8 at hospital 2) consisted of 1 attending physician, 1 junior or senior resident, 2 to 4 interns, and 1 or 2 medical students. Patients were enrolled if study pharmacists (generally 1 pharmacist per weekday per hospital) had time to obtain a medication history prior to discharge. Patients admitted to 1 of 7 randomly chosen medical teams and floors were assigned to the intervention, while patients admitted to the other teams and on different floors received usual care. Thus, patients in the 2 arms were cared for by different physicians and nurses. Randomization was stratified by study hospital and assigned by the principal investigator (J.L.S.) using random number generation in Microsoft Excel (Microsoft Corp, Redmond, Washington). Patients discharged from a nonstudy team or floor, patients transferred between a control team or floor and an intervention team or floor, and patients discharged after June 20, 2006, were excluded. The study was approved by the institutional review board of Partners HealthCare, Boston; patient consent was deemed unnecessary.

**INTERVENTION**

The intervention consisted of an IT application designed to facilitate medication reconciliation, integrated into the inter-
nally developed computerized provider order entry (CPOE) systems at the 2 hospitals, and process redesign involving physicians, nurses, and pharmacists.

**IT APPLICATION: THE PREADMISSION MEDICATION LIST BUILDER**

The medication reconciliation application, the Preadmission Medication List (PAML) Builder, has been previously described. It is a Web-based application that promotes the creation of a preadmission medication list from several electronic sources (including 2 ambulatory electronic medical record systems used at Partners HealthCare and discharge orders from the 2 study hospitals), documents a planned action on admission for each PAML medication (eg, continue on admission, discontinue), facilitates review of a completed PAML and admission medications by a second clinician, and facilitates reconciliation of the PAML with current inpatient medications when discharge orders are written. Features of the PAML Builder application include the following:

- Creation of the preadmission medication list
  1. Displays “medications from electronic sources,” comprising the active medications from the 2 ambulatory electronic medical records used at the 2 study hospitals and the medications ordered at the most recent discharge from the study hospitals.
  2. Allows the admitting clinician to move selected medications from electronic sources into the PAML, with or without changes in dose or frequency; to add new medications (ie, not available in electronic sources) based on the admission medication history; and to update the PAML during the hospitalization as more accurate information becomes available.
- Reconciliation of medications at admission
  1. Requires one of the following planned actions on admission for every medication in the PAML as preparation for writing admission orders: continue as written, discontinue, change in dose/frequency/route, or substitute with a different medication.
  2. Facilitates confirmation of reconciliation by a clinical pharmacist.
- Reconciliation of medications at discharge
  1. Displays the PAML and current inpatient medication orders at the time discharge orders are being written.
  2. Requires confirmation that reconciliation of the PAML with discharge medications has taken place.

At study time, the PAML Builder was not fully integrated with the CPOE system at either study hospital, so PAML medications could not automatically become CPOE admission orders. At discharge, hospital 1 displayed current inpatient medications alongside preadmission medications with the ability to order medications from either list. At hospital 2, these 2 lists existed in separate display windows, and preadmission medications needed to be ordered separately to be resumed at discharge.

**PROCESS REDESIGN**

To implement medication reconciliation successfully, roles and workflows of residents, staff physicians, nurses, and pharmacists at the 2 hospitals were redesigned (Figure 1). Physicians were given primary responsibility for taking preadmission medication histories and referring to this list when ordering medications in the hospital and at discharge. Pharmacists were responsible for confirming the reconciliation process at admission, while nurses were responsible for confirming reconciliation at discharge. Most notably, we replaced redundant medication history taking performed independently and without communication with interdisciplinary collaboration to obtain the most accurate medication history possible; we also used purposeful cross-checking to increase compliance (Figure 1).

Training in process redesign and in the use of the PAML Builder was similar at the 2 hospitals and generally consisted of 30 minutes to 2 hours of small-group training sessions, computer-based training, and e-mail announcements, supplemented by educational handouts, online materials, and IT staff support. Timing of the trial differed in relation to hospitalwide rollout of medication reconciliation at the hospitals. At hospital 1, this study was conducted during the first phase of a phased hospitalwide rollout, so that clinicians were exposed to a wide range of materials publicizing the importance of medication reconciliation (eg, an information booth stationed in the hospital’s main hallway, group and individual e-mails to clinicians, and presentations to hospital leadership). At hospital 2, the study was conducted prior to an all-at-once hospitalwide rollout, with consequently less publicity about medication reconciliation.

Patients in the usual care study arm received the preintervention standard of care. Residents documented medication histories in admission notes; pharmacists reviewed medication orders for appropriateness. At discharge, physicians wrote discharge orders (without facilitated access to preadmission medication histories); nurses educated patients about their medications.

**OUTCOMES**

The main study outcome was the number of unintentional medication discrepancies with potential for causing harm (PADEs) per patient. Defined as “incidents with potential for injury related to a drug,” PADEs have been used as a medication safety measure in numerous studies, and reductions in PADEs due to interventions tend to track with reductions in actual ADEs.

Our process for outcome assessment has been previously described. A “gold standard” preadmission medication history was taken of all study patients by 1 of 2 study pharmacists at each hospital, following a strict protocol but not blinded to intervention status. The resulting preadmission medication list was compared with the medication history taken by the medical team, with all admission medication orders, and with all discharge orders. Discrepancies between the gold standard preadmission medication history and admission or discharge orders were identified, and intentional reasons for changes were sought from the medical record. If necessary and when possible, pharmacists communicated directly with the medical team after discharge orders were written to verify intent. Medication discrepancies that were not clearly intentional were recorded.

Recorded discrepancies were shown by the study pharmacist to rotating adjudication teams of 2 physicians (from a pool of 6) blinded to intervention status. Each medication discrepancy and the patient discharge summary were reviewed. Additional electronic patient information such as ordered medications and test results were reviewed as needed. Using an expert-derived classification scheme, the 2 physicians recorded whether each medication discrepancy was intentional and, if unintentional, the time (admission vs discharge) and type of discrepancy (eg, omission, change in dose). An error in preadmission medication history was recorded as a “history error” (eg, not including aspirin on the preadmission medication list, thus explaining why it is not ordered at discharge). Conversely, an error of reconciling the medication history with medication orders was recorded as a “reconciliation error” (eg, aspirin therapy not restarted at discharge despite being on the preadmission medication list and clinically indicated at discharge). Independently, the 2 reviewers judged the potential for harm for each unintentional discrepancy and its potential severity, as in previous studies. All disagreements were...
resolved by discussion and by a third adjudicator if necessary (needed in 86 of 4700 adjudicated medication discrepancies [1.8%]).

Weekly meetings were conducted to ensure consistency between sites and among study pharmacists and physician adjudicators. Reliability of the gold standard preadmission medication histories and physician adjudication of outcomes have been shown to be moderate to high.16 Prespecified secondary outcomes, based on hospital administrative data, included emergency department visits and hospital readmissions within 30 days of discharge.

**STATISTICAL ANALYSIS**

Patient characteristics and study results were calculated using proportions, means with standard deviations, and medians with interquartile ranges. Poisson log-linear regression was used to determine associations between the number of PADEs per patient and study arm. To adjust for potential confounding, a weighted propensity score approach was used in which the data for each patient were weighted by the inverse of the probability of being in the treatment arm given each of the potential confounding covariates.23 Covariates, chosen a priori on clinical grounds, included patient age, number of outpatient visits within the previous year, inpatient admissions to index hospital within the previous month, number of preadmission medications, number of high-risk preadmission medications, admission source, primary care physician (PCP) from within the hospital network, whether the PCP was the discharging physician, family or caregiver as a source of preadmission medication information, level of training of admitting physician, and patients’ understanding of their medications (subjectively categorized by the study pharmacist as low, medium, or high). High-risk medication classes, based on their risk for causing PADEs in the control group when prescribed, included gout medications, muscle relaxants, hyperlipidemic medications, antidepressants, and respiratory medications.16 Healthcare utilization outcomes were compared using logistic regression with general estimating equations clustered by admitting physician.

Subgroup analyses explored possible effect modification; prespecified subgroups included study hospital, PADE risk score, number of preadmission medications, transfers from outside institutions, level of training of admitting physician, and patient understanding of medications. The PADE risk score, derived from the control group, was calculated by assigning 2 points for patients younger than 85 years and 1 point each for low or medium patient understanding of medications, having 13 or more outpatient visits in the previous year, and having a family member or caregiver as a source of preadmission medication information.16 Interaction terms (ie, subgroup × study arm) were entered into secondary models to evaluate the statistical significance of any effect modification.

Generalized estimating equations, using a robust covariance matrix, were applied to adjust for clustering of results by the admitting physician. Model fit for the propensity score model of the primary outcome was assessed based on aggregates of residuals using the ASSESS statement in SAS statistical software (SAS Institute Inc, Cary, North Carolina), with a P value computed based on 10,000 simulated paths (P = .60, suggesting good model fit). Analyses were intention to treat. P < .05 (2 sided) was considered significant. Analyses were implemented with SAS statistical software, version 9.1 (SAS Institute Inc).

Our target sample comprised 460 patients, which was estimated to provide a 90% power to detect a 60% relative decrease (based on studies of paper-based medication reconciliation3,10) in the presence of any PADE (from 27%3,6,11 to 11%...
of patients), assuming an α level of .05, 5 patients per admitting physician, and an intraclass correlation coefficient by physician of 0.10 (we did not adjust for additional correlation at the team level). The study was not powered to detect a difference in health care utilization.

### RESULTS

#### DESCRIPTION OF STUDY SAMPLE

Of 801 patients originally identified as potentially eligible for the study, 322 were enrolled and were cared for by each of the 14 randomized medical teams and by 117 different admitting physicians. The most common reason for patient exclusion was lack of time for the study pharmacist to obtain a medication history before discharge. Compared with enrolled patients, unenrolled patients had shorter lengths of stay (a table of the characteristics of the study sample and the excluded subjects is available from the corresponding author).

Of 162 patients assigned to the intervention arm, the PAML Builder application was used in 160 patients (99%). A PAML was “completed” (planned actions on admission assigned for all medications and the list signed off as “ready for review” by a pharmacist) within 24 hours of admission for 75 patients (46%), including 42 of 84 patients (50%) at hospital 1 and 33 of 78 patients (42%) at hospital 2 ($P = .35$ for comparison). A PAML was completed prior to discharge in 121 patients (75%). The primary outcome could be evaluated in all 322 patients. Figure 2 shows the study flow. Patient characteristics in the 2 study arms were similar, except for a significantly lower proportion of PCPs within the Partners HealthCare network and a higher proportion of non-medicine interns in the intervention group (Table 1). Some differences were also noted by study hospital (a table of the site differences in baseline patient characteristics is available from the corresponding author).

### EFFECT OF THE INTERVENTION ON PADEs

Among the 162 patients assigned to the intervention, there were 170 unintentional medication discrepancies with potential for patient harm (1.05 PADEs per patient) vs
230 (1.44 PADEs per patient) among the 160 patients assigned to usual care, an adjusted 28% relative risk reduction (Table 2). Ninety-eight PADEs were considered serious, ie, to have potential to cause serious harm such as rehospitalization or persistent alteration in health function, including 43 PADEs in the intervention arm (0.27 per patient) and 55 PADEs in those assigned to usual care (0.34 per patient). The intervention was associated with a significant reduction in PADEs at discharge but not at admission (Table 2). Table 3 gives examples of different types of PADEs identified during the study.

No significant differences were found in health care utilization. The rate of hospital readmission or emergency department visit within 30 days was 20% in the intervention arm and 24% in the usual care arm (clustered odds ratio, 0.76; 95% confidence interval [CI], 0.43-1.35).

In subgroup analyses, we found effect modification by PADE risk score and a suggestion of an effect modification by hospital. The effect of the intervention was greater in the 167 patients with a PADE risk score of 4 or higher (adjusted and clustered relative risk, 0.62; 95% CI, 0.41-0.93) than in the 155 patients with a risk score of 3 or lower (adjusted and clustered relative risk, 1.09; 95% CI, 0.49-2.44) (P value for interaction, .02). The intervention was associated with a significant reduction in PADEs at hospital 1 but not at hospital 2 (P value for interaction, .32) (Table 4). Differences between hospitals were qualitatively similar for the adjusted effect of the intervention on PADEs due to history errors, those due to reconciliation errors, PADEs at admission, and those at discharge (Table 4). No other subgroup differences were found in the effect of the intervention.

**COMMENT**

In this 2-hospital cluster-randomized controlled trial, we found that a medication reconciliation intervention consisting of novel IT and process redesign involving physicians, nurses, and pharmacists was associated with a 28% relative risk reduction in unintentional medication discrepancies with potential for harm, a type of PADE. The absolute risk reduction between the 2 arms was 0.39 PADE per patient or a number needed to treat 2.6 pa-
tients to prevent 1 PADE. The intervention was more successful in patients at high risk for medication discrepancies and possibly more successful at hospital 1 than at hospital 2. To our knowledge, this is the first randomized controlled trial of an IT-based medication reconciliation intervention.

We believe our intervention was successful because it combined effective process redesign with IT. The new reconciliation process encouraged interdisciplinary communication and cross-checks. The PAML Builder application facilitated accurate medication histories by presenting several sources of available medication information, and it displayed the PAML with current inpatient medications during the discharge ordering process.

However, our intervention was far from perfect in eliminating potentially harmful medication discrepancies (1.05 PADEs per patient in the intervention arm). Possible reasons include incomplete and inaccurate electronic sources of ambulatory medications, lack of patient and caregiver knowledge of preadmission medication regimens, lack of clinician adherence with the reconciliation process, and software usability issues (such as ease of adding new medications to the PAML and lack of integration with the admission ordering process).

Our intervention was more successful in patients at high risk for medication discrepancies, based on a risk score derived from the control group. If prospectively validated in other populations, this score could prove useful in prioritizing those most in need of intensive reconciliation efforts, ie, above the minimum Joint Commission standard.7

The intervention reduced PADEs at discharge but not at admission. This result was likely because of the following circumstances: (1) PADEs in general were more common at discharge than at admission; (2) most errors of reconciliation occurred at discharge, and the PAML Builder may have been particularly effective at reducing these kinds of errors; and (3) delays in completing a PAML would also have attenuated the effectiveness of the intervention at admission but not at discharge.

A significant reduction in PADEs with the intervention at hospital 1 but not at hospital 2 could have been due to chance, since the study was not powered to detect a difference in PADEs at each hospital individually. Alternatively, part of the answer may be the phased hospitalwide rollout of the intervention at hospital 1, which led to more publicity about medication reconciliation, possibly resulting in greater compliance with the new processes. Hospital differences related to reducing “medication history errors” may be due in part to greater involvement of nurses at admission at hospital 1. Based on informal, unblinded interviews with clinical personnel conducted after study completion, nurses at hospital 1 more consistently confirmed PAML accuracy at admission compared with hospital 2. Hospital differences in reducing “reconciliation errors” were likely due to differences in discharge medication computer screens developed at the 2 hospitals—a hypothesis we generated a priori. At hospital 1, it was easier to view inpatient and preadmission medications simultaneously and to order medications from either list at discharge.

Regarding other studies of medication reconciliation, 2 recent pre-post studies of paper-based interventions evaluated effects on actual ADEs based on retrospective review of a random selection of medical records, demonstrating a 43% to 84% relative risk reduction.9,10 A recent randomized controlled trial of a pharmacist-run “medication reconciliation and seamless care service” found that 56.3% of 119 control patients had a drug therapy inconsistency or omission at discharge in retrospective medical record review compared with 3.6% of intervention patients (based on an independent review of 17% of intervention patients’ medical records by a second pharmacist).29 Mostly descriptive studies of IT-based medication reconciliation tools are also beginning to be published.30-34 and commercial vendors are starting to provide medication reconciliation modules in their applications.30,35

We believe IT-based medication reconciliation interventions have several advantages over paper-based solutions, including the ability to use existing electronic

---

### Table 2. Incidence and Relative Rates of Potential Adverse Drug Events Due to Unintentional Medication Discrepancies

<table>
<thead>
<tr>
<th>Outcome</th>
<th>PADEs, No. (per Patient) in the Control Arm (n=160)</th>
<th>PADEs, No. (per Patient) in the Intervention Arm (n=162)</th>
<th>Unadjusted RR (95% CI)</th>
<th>Adjusted and Clustered RR (95% CI) a,b</th>
</tr>
</thead>
<tbody>
<tr>
<td>All PADEs</td>
<td>230 (1.44)</td>
<td>170 (1.05)</td>
<td>0.74 (0.60-0.89)</td>
<td>0.72 (0.52-0.99)</td>
</tr>
<tr>
<td>PADEs by type of error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History errors</td>
<td>153 (0.96)</td>
<td>125 (0.77)</td>
<td>0.81 (0.64-1.02)</td>
<td>0.80 (0.55-1.15)</td>
</tr>
<tr>
<td>Reconciliation errors</td>
<td>80 (0.50)</td>
<td>52 (0.32)</td>
<td>0.64 (0.45-0.91)</td>
<td>0.62 (0.29-1.34)</td>
</tr>
<tr>
<td>PADEs by time of occurrence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PADEs at admission</td>
<td>49 (0.31)</td>
<td>44 (0.27)</td>
<td>0.89 (0.59-1.33)</td>
<td>0.87 (0.51-1.52)</td>
</tr>
<tr>
<td>PADEs at discharge</td>
<td>181 (1.13)</td>
<td>126 (0.78)</td>
<td>0.69 (0.55-0.86)</td>
<td>0.67 (0.49-0.98)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; RR, relative risk.

a Adjusted for clustering by admitting physician using general estimating equations.

b Propensity score–adjusted model. Propensity score based on patient age, number of outpatient visits within the previous year, inpatient admissions to the index hospital within the previous month, number of preadmission medications, number of high-risk preadmission medications, admission source, primary care physician from within the hospital network, whether the primary care physician was the discharging physician, family or caregiver as a source of preadmission medication information, level of training of the physician documenting the medication history, and patient understanding of their medications. Except for patient understanding of their medications, which was dichotomized as high vs medium or low, all other variables were categorized as in Table 1.

c Three PADEs in the control arm and 7 PADEs in the intervention arms were attributed to both history error and reconciliation error.
sources of ambulatory medication information, better integration into workflow in hospitals with CPOE, easier sharing of reconciliation information across providers, automatic production of documentation for discharge summaries, comparisons of medication lists to facilitate reconciliation and patient education, provision of alerts and reminders to ensure compliance, and ability to track compliance to inform further process improvement.

This study has several limitations. First, because it was conducted on general medical services at academic hospitals, results may not be generalizable to other settings. Patients with very short lengths of stay may have been disproportionately discharged before enrollment, leading to selection of a sicker patient population; the results may not be generalizable to less sick patients or those taking fewer medications. Second, the study measured potential and not actual ADEs, and while we analyzed health care utilization, the study was not powered to detect a reduction in this outcome. Third, full use of the PAML Builder was not achieved: only 46% of patients had a completed PAML within 24 hours of admission (although 75% were complete by discharge), thus limiting the ability of the intervention to benefit patients. Based on an analysis of clinician attitudes and patterns of use of the application, we attribute this nonadherence to the lack of integration of the application with CPOE at admission. This problem has since been remedied; currently 80% to 90% of PAMLs are complete within 24 hours of admission. Fourth, we cannot exclude the possibility of unmeasured provider characteristics confounding the

Table 3. Examples of Potential Adverse Drug Events

<table>
<thead>
<tr>
<th>History</th>
<th>Timing of Error</th>
<th>Type of Error</th>
<th>Reason for Error</th>
<th>Potential Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A patient with multiple cardiac risk factors was admitted for atypical chest pain. At home he was taking atenolol, 100 mg by mouth daily. The medical team accurately documented this medication in the preadmission medication list but did not prescribe it (or any other β-blocker) on admission or any time during the hospitalization. No medical reason could be found for withholding it, and notes document a plan to continue optimal medical management of possible coronary disease. The patient was discharged on his home dose of atenolol.</td>
<td>Admission</td>
<td>Omission</td>
<td>Reconciliation error</td>
<td>Serious</td>
</tr>
<tr>
<td>A patient with a seizure disorder was admitted for peripheral edema and COPD exacerbation. At home the patient was taking carbamazepine, 100 mg by mouth twice daily, but the medical team incorrectly documented 100 mg by mouth 3 times a day in the preadmission medication list and then prescribed that frequency on admission. No blood levels of the medication were drawn during the hospitalization.</td>
<td>Admission</td>
<td>Frequency</td>
<td>History error</td>
<td>Serious</td>
</tr>
<tr>
<td>A patient with a history of asthma was admitted for an asthma exacerbation. At home, the patient was using an albuterol inhaler, 2 puffs every 4 hours as needed for shortness of breath. The team accurately documented the medication in the preadmission medication list. During the hospitalization the patient was given albuterol by nebulizer. At discharge, no albuterol (or any other short-acting bronchodilator) was prescribed.</td>
<td>Discharge</td>
<td>Omission</td>
<td>Reconciliation error</td>
<td>Serious</td>
</tr>
<tr>
<td>A patient with gastroesophageal reflux disease was admitted with nausea and vomiting and was found to have hyponatremia. At home, the patient was taking omeprazole 20 mg by mouth daily, but the medical team did not document this medication in the preadmission medication list. During hospitalization, the patient was prescribed esomeprazole for stress ulcer prophylaxis. At discharge, no proton pump inhibitor or other antireflux medication was prescribed.</td>
<td>Discharge</td>
<td>Omission</td>
<td>History error</td>
<td>Significant</td>
</tr>
<tr>
<td>A patient with a history of myocardial infarction and hypertension was admitted for a gastrointestinal bleed. At home the patient was taking lisinopril, 10 mg by mouth daily, but the medical team incorrectly documented 25 mg by mouth daily in the preadmission medication list. During hospitalization the patient was hypertensive, and the team appropriately ordered captopril instead of lisinopril to manage his blood pressure. At discharge, with a normal blood pressure, the team ordered what they thought was his home dose of lisinopril, 25 mg by mouth daily.</td>
<td>Discharge</td>
<td>Dose</td>
<td>History error</td>
<td>Serious</td>
</tr>
</tbody>
</table>

Abbreviation: COPD, chronic obstructive pulmonary disease. In all cases, errors were corrected prior to finalization of the discharge orders.
results, but the factors we adjusted for had no effects on study findings. Finally, hypotheses about the effects of the intervention’s rollout or the involvement of nurses in the medication history process at the 2 hospitals were generated post hoc and may be biased.

In conclusion, an interdisciplinary medication reconciliation intervention comprising novel IT and process redesign was associated with a significant reduction in unintentional medication discrepancies with potential for harm. Institutions should strongly consider adopting electronic medication reconciliation tools as availability increases. Site-specific differences suggest that electronic medication reconciliation tools should facilitate comparisons of medication lists at transition points and use of these lists to order medications for the next care setting. Provider education on taking complete medication histories and purposeful “independent redundancies” in the reconciliation process (eg, nurses verifying the accuracy of physician-produced medication histories) are also likely important to the success of any medication reconciliation effort. Future research should be directed at more rigorous evaluations of the environments, medication reconciliation interventions, and implementation characteristics that best improve outcomes and at further development and evaluation of commercially available electronic medication reconciliation tools. Ideally, multicenter studies using methods such as randomized controlled trials or interrupted time series analyses should be conducted using more downstream health outcomes (such as total ADEs and hospital readmissions). More work is needed to eliminate serious medication reconciliation errors and make transitions in care as safe as possible.

Accepted for Publication: December 6, 2008.

Author Affiliations: Brigham and Women’s Academic Hospitalist Service (Drs Schnipper and Carty), Division of General Medicine (Drs Schnipper, Carty, Poon, Lipsitz, and Gandhi and Mr Ndumele and Ms Liang), Center for Clinical Excellence (Drs Carty and Gandhi), and Pharmacy Services (Dr Labonville), Brigham and Women’s Hospital, Boston, Massachusetts; Department of Medicine (Dr Hamann, Karson, Bhan, and Coley), Geriatric Medicine Unit (Dr Hamann), Center for Quality and Safety (Dr Karson and Ms McCarthy), and Pharmacy Services (Dr Diedrichsen), Massachusetts General Hospital, Boston; Partners Information Systems Clinical Informatics Research and Development, Boston (Drs Poon, Turchin, and Broverman); and Harvard Medical School, Boston (Drs Schnipper, Hamann, Carty, Karson, Bhan, Coley, Poon, Turchin, Lipsitz, and Gandhi).

Correspondence: Jeffrey L Schnipper, MD, MPH, Division of General Medicine, Brigham and Women’s Hospital, 1620 Tremont St, Boston, MA 02120-1613 (jschnipper@partners.org).

Author Contributions: Dr Schnipper had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Schnipper, Carty, Karson, Poon, Broverman, and Gandhi. Acquisition of data: Schnipper, Hamann, Carty, Karson, Bhan, Labonville, Diedrichsen, and Gandhi. Analysis and interpretation of data: Schnipper, Hamann, Ndumele, Liang, Coley, Poon, Turchin, Lipsitz, McCarthy, and Gandhi. Drafting of the manuscript: Schnipper. Critical revision of the manuscript for important intellectual content: Hamann, Ndumele, Liang, Carty, Karson, Bhan, Coley, Poon, Turchin, Labonville, Diedrichsen, Lipsitz, Broverman, McCarthy, and Gandhi. Statistical analysis: Schnipper, Ndumele, and Lipsitz. Obtained funding: Schnipper, Coley, Broverman, and Gandhi. Administrative, technical, and material support: Liang, Karson, Coley, and McCarthy. Study supervision: Broverman.

Financial Disclosure: None reported.

Funding/Support: This study was funded in part by an investigator-initiated grant from the Harvard Risk Management Foundation, including compensation for Elisabeth Burdick, MS, Amy Bloom, MPH, and Emily Barsky, BA, as well as internal funding from Brigham and Women’s Hospital (BWH), Massachusetts General Hospital, and Partners HealthCare. Dr Schnipper was supported by a mentored clinical scientist award from the National Heart, Lung, and Blood Institute (K08 HL072806).

Role of the Sponsors: The funding organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

Previous Presentations: Portions of this work were presented as a poster at the Summer Meeting of the American Society of Health-System Pharmacists; June 25, 2007; San Francisco, California; and was presented orally as an abstract at the Society of General Internal Medicine Annual Meeting; April 10, 2008; Pittsburgh, Pennsylvania.

Additional Contributions: The following Partners Information Systems personnel were involved in developing this intervention: Barry Blumenfeld, MD, Cheryl Van Putten, PMP, John Poikonen, BA, Eric Godlewski, BA, Linda Moroni, MBA, Michael McNamara, BA, Sandra Smith, BA, Marilyn Paterno, MBA, Daniel Fuchs, BS, Oliver James, BS, and Greg Rath, BA. The BWH medication reconciliation implementation team included Erin Graydon-Baker, MS, RRT, Christine McCormack, BA, Christina Pelletier, BA, Emily Maher, MD, Ellen Bergeron, RN, MSN, Jennifer Kuzemchak, BA, Michael Cotugno, RPh, and Andrea Giannattasio, BA. The Massachusetts General Hospital medication reconciliation implementation...
tation team included George Baker, MD, Sally Millar, RN, and Margaret Clapp, BA. Bonnie Greenwood, Pharm D, and Trisha LaPointe, Pharm D, BCPS, assisted in pharmacist data collection; and BWH personnel John Orav, PhD, provided for biostatistical assistance, Elisabeth Burdick, MS, assisted in statistical programming, Amy Bloom, MPH, assisted in project management, and Emily Barsky, BA, Eric Tomasini, BA, and Emily Dattwyler, BA, provided research assistance. Jaylyn Olivo and Jeanne Zimmerman at BWH provided editorial assistance.

REFERENCES

15. Vira T, Colquhoun M, Etchells E. Reconcilable differences: correcting medica-