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Research

Incidence of clinically relevant medication errors in the era of electronically prepopulated medication reconciliation forms: a retrospective chart review

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Abstract

Background: To reduce medication discrepancies (unintended differences between a patient's outpatient and inpatient medication regimens), Canadian institutions have implemented medication reconciliation forms that are prepopulated with outpatient medication dispensing data. These may prompt prescribers to reorder discontinued medications or continue newly contraindicated medications. Our objective was to evaluate the incidence of medication discrepancies and errors of commission after the implementation of such forms.

Methods: This retrospective chart review included patients previously enrolled in an observational study in which a research pharmacist prospectively collected best-possible medication histories in the emergency department. Research assistants uninvolved with the parent study compared medication orders written in the first 48 hours after admission with the research pharmacist's best-possible medication history to identify medication discrepancies and errors of commission, defined as inappropriate medication continuations and reordering of previously stopped medications. An independent panel adjudicated the clinical significance of the errors.

Results: Of 151 patients, 71 (47.0% [95% confidence interval (CI) 39.2–54.9]) were exposed to 112 medication errors on admission. Of the 112 errors, 24 (21.4% [95% CI 14.9–29.9]) were clinically significant. Errors of commission accounted for 24.1% (27/112 [95% CI 17.3–32.8]) of all errors; 10 (37.0% [95% CI 18.8–55.2]) of the errors of commission were clinically significant.

Interpretation: Medication errors were common after the implementation of electronically prepopulated medication reconciliation forms. Prospective research is required to examine the impact of prepopulated medication reconciliation forms and ensure they do not facilitate errors of commission.

Medication discrepancies are unintended differences between a patient's outpatient and inpatient medication regimens. They affect up to 60% of patients admitted to hospital.[1,2] Medication discrepancies can lead to adverse drug events — unintended and harmful effects associated with medications[1–3] — which are a common cause of preventable iatrogenic morbidity and mortality.[4–6]

Medication reconciliation is a required organizational practice in Canadian hospitals.[7] It involves obtaining and documenting a best-possible medication history on admission in order to improve communication at care transitions and prevent medication discrepancies.[7] Several international studies have shown a reduction in medication discrepancies among inpatients following the implementation of medication reconciliation interventions.[8–14] However, most published interventions relied heavily on pharmacists, limiting their generalizability to institutions with adequate pharmacy resources. Most Canadian hospitals have insufficient clinical pharmacists and rely on physicians, nurses and clinical trainees to complete medication reconciliation, even though these people often lack the time to take a thorough medication history.[15–18]

To facilitate medication history-taking and eliminate transcribing errors, hospitals in jurisdictions with access to elec-

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tronic medication dispensing records have developed medication reconciliation forms that are prepopulated with outpatient medication dispensing data. Yet, such databases do not capture medications dispensed outside of community pharmacies (e.g., in long-term care facilities) and may list inaccurate dosages of medications titrated by patients or care providers (e.g., warfarin).[19,20] Prepopulated medication reconciliation forms may facilitate errors of commission by prompting health care providers to restart a discontinued medication that remains in the electronic medication dispensing history or to continue a medication in the setting of a new contraindication. Our objective was to evaluate the incidence of medication discrepancies and errors of commission after implementation of an electronically prepopulated medication reconciliation form. A secondary objective was to evaluate factors associated with both types of error.

Methods

Design

We conducted a structured 2-staged chart review at Vancouver General Hospital, a 955-bed academic tertiary care centre. This was an a priori planned substudy of a large prospective observational cohort study that aimed to validate previously derived clinical decision rules to identify patients at high risk for adverse drug events.[21]

Participants

We included patients who had been enrolled into the prospective study and were subsequently admitted to hospital between Oct. 1, 2014 and Aug. 31, 2015. Patients had been enrolled into the prospective study by means of a systematic selection algorithm to minimize selection bias and ensure a representative sample.[21] We included patients who were 19 years of age or older, spoke English or had an interpreter available, and had taken at least 1 prescription or over-the-counter medication within 2 weeks of presenting to the emergency department. We excluded patients whose charts were unavailable for review and those with a hospital stay lasting less than 24 hours.

Definitions

We defined a medication discrepancy as any unexplained difference between medication orders documented on medication reconciliation forms or other order sheets within 48 hours of admission and a best-possible medication history recorded by a research pharmacist. Discrepancies included discontinuations and omissions of home medications; changes in the dosage, route or frequency of administration; and ordering an "as needed" medication regularly or vice versa (Table 1). We defined an error of commission as reordering a medication that had been previously stopped or inappropriately continuing a medication known to exacerbate a patient's clinical condition (e.g., continuing an antihypertensive in the setting of hypotension). We did not consider substituting a brand-name medication for its generic equivalent or an agent within the same pharmacologic class as discrepancies. We excluded discrepancies involving herbal products, vitamins and supplements.

We rated clinical severity based on a previously published classification system:[1] class I errors were those deemed "unlikely to cause patient discomfort or clinical deterioration," class II errors had "the potential to cause moderate discomfort or clinical deterioration," and class III errors were defined as having "the potential to result in severe discomfort or clinical deterioration."

Collection of best-possible medication history data

During the prospective study, a research pharmacist (K.B.) collected and documented a best-possible medication history for all patients in the emergency department using a variety of information sources including patient and family member interviews, PharmaNet (British Columbia's electronic medication dispensing database), nursing home medication records, medication bottles, blister packs and collateral sources of information, if required. We retained the pharmacist-collected best-possible medication history in the research records of the parent study and considered it to be the gold standard.

Chart review methods

Stage 1

Two research assistants (K.S. and S.L.) uninvolved in the parent study and blinded to the best-possible medication history collected by the research pharmacist reviewed the charts of eligible patients after they had been discharged from hospital. The research assistants abstracted all medication orders written within 48 hours of admission, including those documented on medication reconciliation forms (Figure 1) and regular order sheets, using a standardized data collection form. They also recorded demographic data and clinical information pertaining to the admission. To assess interrater reliability, the research assistants independently reviewed a random sample of 20 charts during a pilot period. All data were collected with the use of Epi Info version 7.1.4 (Centers for Disease Control and Prevention).

Stage 2

One of the research assistants (K.S.), a medical resident, then compared admission orders identified during stage 1 with the research pharmacist's best-possible medication history and documented medication discrepancies and errors of commission. If errors were identified, the entire chart was reviewed for any adverse drug events that occurred during the admission as a result of the error. During the pilot period, it became apparent that we could not determine intentionality retrospectively. Therefore, we categorized inappropriate discrepancies as "unexplained" or "explained." We categorized discrepancies as explained when we found evidence in nursing or physician notes, or in laboratory or diagnostic data, that warranted holding the medication (e.g., holding an angiotensin-converting-enzyme inhibitor in the setting of an elevated creatinine level). Explained discrepancies were not considered errors.

Stage 3

An adjudication panel consisting of an internist and geriatrician (D.V.), an emergency physician (C.H.) and a clinical pharmacist (K.D.), all of whom were uninvolved in stages 1 and 2, independently adjudicated medication errors according to their potential to cause harm. All disagreements were resolved by discussion. We calculated the interrater reliability among the 3 members of the adjudication panel for classifying the type and severity of errors by collapsing class II and III discrepancies into a single category.

Statistical analysis

We computed descriptive statistics for demographic variables and medication error classifications, and reported summary statistics as means and standard deviations for continuous variables, and as proportions with 95% confidence intervals (CIs) for categorical variables. We assessed the agreement between raters by calculating Fleiss κ scores with 95% CIs.[22] We analyzed the association between unexplained discrepancies and potentially important variables using nonparametric Mann–Whitney tests, as the outcome data did not follow a normal distribution. Potentially important variables were determined by a literature review on medication discrepancies and adverse drug events.[1,21] We used logistic regression to examine univariate associations between the occurrence of a discrepancy and key predictor variables, then built a regression model to calculate the adjusted odds of occurrence of a discrepancy. The sample size was determined by the primary study.

Table 1: Categories of medication error

Type of error	Definition	Example
Medication discrepancy		
Discontinuation	Discontinuing a patient's regular medication without explanation	Patient is taking 20 mg of citalopram at home, but this is discontinued on admission to hospital
Omission	Patient's regular medication is not listed on medication reconciliation form and is not reordered	Patient is taking 81 mg of acetylsalicylic acid (over the counter) daily, but this is not listed on medication reconciliation form. It is not ordered during hospital stay.
Change in dosage	Medication is ordered at dosage indicated on medication reconciliation form, but patient is taking different dosage	Patient was prescribed 25 mg of metoprolol twice daily, but family doctor had decreased dosage to 12.5 mg by mouth twice daily. Patient receives 25 mg twice daily in hospital without indication for increased dosage.
Change in route	Medication is ordered via route indicated on medication reconciliation form, but patient is taking it differently at home	Patient was prescribed acetaminophen, 1000 mg by mouth 3 times daily per rectum, in nursing facility because of decreased level of consciousness. It is ordered by mouth in hospital.
Change in frequency	Medication is ordered at frequency indicated on medication reconciliation form, which differs from patient's regimen	Patient was prescribed gabapentin, 300 mg 3 times daily, but is taking it only at bedtime because of daytime somnolence. Medication is ordered as 300 mg 3 times daily in hospital.
As needed to regular	Medication is ordered regularly as per medication reconciliation form, but patient is taking it as needed	Patient was prescribed zopliclone, 7.5 mg at bedtime, but is using it as needed, and only infrequently. It is ordered regularly in hospital.
Regular to as needed	Medication is ordered as needed as per medication reconciliation form, but the patient is taking it regularly	Patient was prescribed lorazepam, 0.5–1 mg 3 times daily as needed, but is taking 1 mg 3 times daily regularly. It is ordered as needed in hospital.
Error of commission		
Reorder error	Reordering a medication that had previously been stopped	Patient was prescribed indomethacin for acute gout flare-up but had stopped it when flare-up subsided. It is erroneously reordered in hospital.
Inappropriate continuation	Ordering a medication that patient is taking in the setting of a new contraindication	Patient is taking indomethacin for acute gout flare-up and then presents with gastrointestinal bleed. Indomethacin is inappropriately continued in hospital.

Ethics approval

The University of British Columbia Clinical Research Ethics Board approved the study protocol and waived the need for informed consent.

Results

Of the 189 patients enrolled in the primary study who were admitted to hospital, 38 were excluded: in 27 cases the chart

IF YOU RECEIVED THIS FACSIMILE IN ERROR, PLEASE CALL 999-999-9999 IMMEDIATELY

Vancouver CoastalHealth

Facility Patient Label

MEDICATION RECONCILIATION ORDERS
(Page X of X)
Printed on: 2016 Oct 01 09:04

PATIENT, TEST
Birthdate: **1955 Jun 2** Gender: **F**
PHN: **BC-XXXXXXXXX**

Clinical Information as per PharmaNet:
Adverse Reaction(s) as per PharmaNet (refer to facility-specific documentation for current status): NKDA

Medication History **Medications as per PharmaNet on 2016 Oct 01 09:04**	**Verified with:** ☐ patient ☐ other:	Request medical interpreter: 604-675-4099 **Medication Orders**
FLUTICASONE PROPRIONATE 250 MCG HFA AER INHALE 1 PUFF ONCE DAILY (RINSE MOUTH AFTER USE) 2016Sept15 Qty: 120.0 Filled BROWN CPSID: 91/02797 (Max Daily Dose: 1.000 per PharmaNet)	☐ Taking differently (specify): ☐ Per PharmaNet ☐ No longer taking ☐ Unable to verify Last taken at:	☐ Give as per verified history ☐ Give as per PharmaNet ☐ Discontinue ☐ Change to:
MORPHINE 6O MG ER CAP TAKE ONE CAPSULE TWICE DAILY 2016Sept15 Qty: 60.0 Filled BROWN CPSID: 91/02797 (Max Daily Dose: 1.000 per PharmaNet)	☐ Taking differently (specify): ☐ Per PharmaNet ☐ No longer taking ☐ Unable to verify Last taken at:	☐ Give as per verified history ☐ Give as per PharmaNet ☐ Discontinue ☐ Change to:
MORPHINE 5 MG TAB TAKE 1 TABLET EVERY 4 HOURS WHEN NEEDED FOR BREAK THROUGH PAIN 2016Sept15 Qty: 28.0 Filled BROWN CPSID: 91/02797 (Max Daily Dose: 1.000 per PharmaNet)	☐ Taking differently (specify): ☐ Per PharmaNet ☐ No longer taking ☐ Unable to verify Last taken at:	☐ Give as per verified history ☐ Give as per PharmaNet ☐ Discontinue ☐ Change to:

Medication History taken by:
[ ] Prescriber or
Designation_____ **Date and Time:** _____
Signature / Initials: _____

Requested by: ANurse1
91/13867 Dr. ADoctor, JOHN at BC01000120 EXC TEST – VGH ED
Form No. VCH.VA.VGH.0268

Prescriber:
_____ _____
Date **Time**
Signature
_____ _____
Printed Name **College ID**

PLACE ORIGINAL IN ORDERS SECTION OF THE CHART
FAX ALL PAGES TO PHARMACY

Figure 1: Prepopulated medication reconciliation form for a hypothetical patient. Electronic medication dispensing data from PharmaNet are used to automatically prepopulate medication reconciliation forms. A member of the health care team must verify the patient's medication history and note in the middle column any discrepancies between the prepopulated information and how the patient is taking the medication. The treating physician then indicates in the right-hand column whether to continue or alter the medication.

was not available for review, 8 patients had a stay of less than 24 hours, and 3 patients had an incomplete best-possible medication history. Thus, we reviewed the charts of 151 patients. The mean age of the participants was 66.8 (standard deviation 18.8) years, and 80 (53.0%) were male (Table 2). The mean number of medications on admission was 6.8 (standard deviation 4.7), and the most common admitting diagnoses were pneumonia, cancer and sepsis.

The interrater reliability between research assistants in documenting medication orders was 0.91 (κ 95% CI 0.78–1.0). Eight patients did not have a prepopulated medication reconciliation form in their chart. Of the 143 charts containing medication reconciliation forms, 46 (32.2% [95% CI 25.0–40.2]) had the medication verification section (i.e., middle column of the form; Figure 1) completed by a health care provider (residents in 18 cases [39% (95% CI 26.4–53.6)], clinical pharmacists in 12 cases [26% (95% CI 15.6–40.3)], medical students in 9 cases [20% (95% CI 10.7–3.3.2)], attending physicians in 6 cases [13% (95% CI 6.2–25.7)] and a nurse in 1 case [2% (95% CI 0.5–11.2)]). In all the other charts, health care providers simply ticked off boxes to order medications in the third column, without completing the medication verification section.

Incidence of medication errors

Of the 151 patients, 71 (47.0% [95% CI 39.2–54.9]) were exposed to 112 medication errors on admission. We identified 85/112 (75.9% [95% CI 67.1–82.9]) unexplained medication discrepancies among 49 patients (Table 3). Most of the discrepancies were categorized as inappropriate discontinuations (32/85 [38% (95% CI 27.3–47.9)]) and omissions (24/85 [28% (95% CI 18.6–37.8)]). A total of 27/112 (24.1% [95% CI 17.3–32.8]) errors of commission were identified among 22 patients (Table 3). These included 10 inappropriate continuations of contraindicated medications (37% [95% CI 21.5–55.9]) and 17 reorder errors of previously stopped medications (63% [95% CI 44.1–78.5]).

Clinical significance

The interrater reliability among the 3 members of the adjudication panel for classifying the severity of errors was 0.33 (κ 95% CI 0.28–0.42). Thirteen of the 85 medication discrepancies (15% [95% CI 10.1–25.7]) were deemed as having the potential to cause moderate harm (class II), and 1 (1% [95% CI 0.0–3.5]) was classified as having the potential to result in severe clinical deterioration (class III) (Table 3). Of the 27 identified errors of commission, 10 (37% [95% CI 18.8–55.2]) were assigned a class II rating, and none were assigned a class III rating. Of the 24 clinically significant (class II and class III) errors, 6 (25% [95% CI 12.1–45.1]) involved continuing a patient's antihypertensive medication in the setting of symptomatic hypotension, and 4 (17% [95% CI 6.8–36.1]) were an omission of low-dosage acetylsalicylic acid (Table 4). We found no documented adverse drug events as a result of medication errors.

Factors associated with medication errors

Univariate analysis indicated that taking 8 or more medications and the presence of cognitive impairment were associated with unexplained medication discrepancies ($p < 0.001$, $p = 0.05$, respectively) (Table 5). Similarly, taking 8 or more medications was associated with errors of commission ($p = 0.02$).

Multivariable analyses indicated that taking 8 or more medications was associated with a fivefold greater odds of experiencing 1 or more medication discrepancies or errors of commission (odds ratio 5.05 [95% CI 2.44–10.46], $p < 0.001$) after known confounders were controlled for (Table 6). Age, sex, timing of admission and length of admission were not associated with the occurrence of medication discrepancies or errors of commission.

Interpretation

We found at least 1 medication discrepancy or error of commission in the charts of 47.0% of enrolled patients. Errors of

Table 2: Characteristics of participants

Characteristic	No. (%)* n = 151
Sex	
Male	80 (53.0)
Female	71 (47.0)
Age, mean ± SD, yr	66.8 ± 18.8
Length of hospital stay, median (IQR), d	6 (3–13)
Most responsible diagnosis	
Pneumonia	14 (9.3)
Cancer	11 (7.3)
Sepsis	9 (6.0)
Stroke syndrome	8 (5.3)
Extremity fracture	7 (4.6)
Upper gastrointestinal bleed	6 (4.0)
Chronic obstructive pulmonary disease	4 (2.6)
Skin/soft tissue infection	4 (2.6)
Bipolar affective disorder	4 (2.6)
Asthma	3 (2.0)
Comorbid condition	
Hypertension	68 (45.0)
Dyslipidemia	29 (19.2)
Diabetes mellitus type 2	25 (16.6)
Atrial fibrillation	24 (15.9)
Depression/anxiety	21 (13.9)
Hypothyroidism	21 (13.9)
Gastroesophageal reflux disease	20 (13.2)
Coronary artery disease	19 (12.6)
Congestive heart failure	18 (11.9)
Osteoarthritis	18 (11.9)
No. of medications on admission, mean ± SD	6.8 ± 4.7

Note: IQR = interquartile range, SD = standard deviation.
*Except where noted otherwise.

Table 3: Type and clinical severity* of errors

Type of error	No. (%)			
	Overall	Class I	Class II	Class III
Medication discrepancy				
Discontinuation	32 (38)	29 (91)	2 (6)	1 (3)
Omission	24 (28)	19 (79)	5 (21)	0
Change in dosage	15 (18)	11 (73)	4 (27)	0
Change in frequency	6 (7)	5 (83)	1 (17)	0
As needed to regular	6 (7)	5 (83)	1 (17)	0
Regular to as needed	2 (2)	2 (100.0)	0	0
Total	85 (100)	71 (84)	13 (15)	1 (1)
Error of commission				
Reordering error	17 (63)	14 (82)	3 (18)	0
Inappropriate continuation	10 (37)	3 (30)	7 (70)	0
Total	27 (100)	17 (63)	10 (37)	0

*Based on a previously published classification system:[1] class I errors were those deemed "unlikely to cause patient discomfort or clinical deterioration," class II errors had "the potential to cause moderate discomfort or clinical deterioration," and class III errors were defined as having "the potential to result in severe discomfort or clinical deterioration."

commission were found in 14.6% of the charts, of which 37.0% were clinically significant. The medication history section of prepopulated medication reconciliation forms was left blank in 67.8% of the charts.

We found a lower incidence of medication discrepancies overall (32.4% [49 of 151 patients] v. 53.6%) and of clinically significant discrepancies (16.5% v. 38.6%) than Cornish and colleagues,[1] who conducted a prospective study in a Canadian teaching hospital without access to electronic medication dispensing data. Kalb and colleagues[2] conducted a small prospective study following the launch of PharmaNet but before the implementation of prepopulated medication reconciliation forms and reported discrepancies among 60% of inpatients, 43% of which were deemed clinically significant. International studies with varied methodologies have shown unintentional medication discrepancies among 27%–54% of patients, 11%–59% of which were deemed to be clinically important.[5,6,23]

We found a high incidence of errors of commission compared with Cornish and colleagues[1] (17.9% v. 0%). Our reported incidence is similar to that reported by Kalb and colleagues,[2] 27%, after PharmaNet data became available to hospital prescribers. Our finding may be a reflection of prescribers' overreliance on dispensing data in lieu of taking a careful medication history and verifying medication dispensing data. This overreliance may be compounded by the ease of ticking boxes on prepopulated forms. Although our study was not comparative, and we therefore cannot determine the impact of prepopulated medication reconciliation forms on the incidence of medication discrepancies or errors of commission, our data suggest that errors of commission occur frequently when medication dispensing data are available to prescribers. These types of error are as harmful as, or potentially more harmful than, the medication discrepancies that reconciliation processes were designed to prevent.

Most patients in our study did not have medication histories verified on the medication reconciliation form, and only 12 patients (8.4%) had medication histories documented by clinical pharmacists. Several studies have shown a reduction in both overall and clinically significant medication discrepancies when clinical pharmacists are involved in reconciling medications. This suggests that clinical pharmacist resources should be made available for medication reconciliation processes in Canadian acute care hospitals.[3,14,24,25] Given the scarcity of pharmacist resources in Canada, this may be feasible only for patients at high risk for adverse drug events. Based on our findings, this may include patients taking at least 8 medications and those with cognitive impairment. Our data are consistent with a recent Canadian study that showed a significant increase in medication discrepancies among patients prescribed at least 7 medications on discharge.[26]

Limitations

Our study has several limitations. Our sample size was limited by enrolment into the parent study. Our study was retrospective, and, therefore, we were unable to confirm intentionality for the identified discrepancies when clinical notes were unclear. Although the interrater reliability on the collection of medication orders was excellent, the interrater reliability on rating their clinical significance was only fair. This likely reflects the varied clinical backgrounds of our adjudication panel members as well as the complexity of determining the potential clinical significance of a medication error in the absence of an adverse drug event. Although we used a prospectively collected best-possible medication history obtained

Table 4: Description of the 24 identified errors classified as class II/III errors

Admission diagnosis	Description of error	Type and clinical significance
Extremity fracture	Patient had drug-eluting stent placed within previous year and was taking dual antiplatelet therapy; acetylsalicylic acid was omitted from admission orders	Omission, class III
	Perindopril–indapamide was ordered on admission; however, this medication had been previously stopped and patient was no longer taking it	Reorder error, class II
Upper gastrointestinal bleed	Patient's hydrochlorothiazide was reordered despite symptomatic hypotension at presentation	Inappropriate continuation, class II
	Gliclazide was ordered on admission; however, this medication had been previously stopped and patient was no longer taking it	Reorder error, class II
Pneumonia, COPD	Patient's budesonide was omitted despite regular use in setting of severe COPD	Omission, class II
Depression	Patient's budesonide–formoterol was discontinued on admission orders despite regular use in setting of severe COPD and asthma	Discontinuation, class II
	Patient's prednisone was discontinued on admission orders despite regular use	Discontinuation, class II
Syncope	Patient's hydrochlorothiazide was continued despite symptomatic orthostatic hypotension at presentation	Inappropriate continuation, class II
Schizophrenia	Patient's zuclopenthixol was ordered as 60 mg intramuscularly every 2 wk as per PharmaNet; however, patient was taking 40 mg intramuscularly every 2 wk	Change in dosage, class II
Weakness	Patient's acetylsalicylic acid was omitted from admission orders (indication transient ischemic attacks)	Omission, class II
Asthma	Indomethacin was ordered on admission; however, patient was no longer taking this medication	Reorder error, class II
Dyspnea	Patient's acetylsalicylic acid was omitted from admission orders (indication coronary artery disease)	Omission, class II
Fall	Patient's amlodipine was continued despite symptomatic hypotension	Inappropriate continuation, class II
Cancer	Celecoxib was ordered regularly as per PharmaNet; however, patient took this as needed	As needed to regular, class II
Pulmonary embolism	Patient's metoprolol was continued despite symptomatic hypotension	Inappropriate continuation, class II
	Patient's perindopril was continued despite symptomatic hypotension	Inappropriate continuation, class II
	Patient's acetylsalicylic acid was omitted from admission orders (indication coronary artery disease)	Omission, class II
Hypovolemia, atrial flutter	Imatinib was ordered on admission as per PharmaNet; however, patient was no longer taking this medication	Reorder error, class II
Transient ischemic attack	Patient was taking 7.5 mg of zopiclone at bedtime; however, it was ordered as 11.25 mg at bedtime as needed as per PharmaNet	Change in dosage, class II
Pneumonia, sepsis	Patient was taking dantrolene, 100 mg 4 times daily, but it was ordered as 400 mg 4 times daily as per PharmaNet	Change in dosage, class II
Urinary tract infection, sepsis	Patient was using fluticasone regularly for asthma but this was omitted	Omission, class II
Urinary tract infection	Patient was taking carbidopa–levodopa extended release 3 times daily and at bedtime as needed; however, this was ordered as once daily as per PharmaNet	Change in frequency, class II
Sepsis	Patient was taking methadone, 3 mg every 8 h, but this was ordered as 2 mg every 8 h as per PharmaNet	Change in dosage, class II
Pyelonephritis	Patient's bisoprolol was continued in setting of symptomatic hypotension	Inappropriate continuation, class II

Note: COPD = chronic obstructive pulmonary disease.

Table 5: Univariate association between patient characteristics and errors

Type of error; characteristic	No. of errors per patient, mean ± SD: With characteristic	Without characteristic	Difference (95% CI)
Medication discrepancy			
Nighttime admission (after 8 pm)	0.43 ± 0.81	0.61 ± 1.11	0.18 (–0.19 to 0.57)
Length of stay ≥ 48 hr	0.57 ± 1.06	0.46 ± 0.78	–0.11 (–0.71 to 0.49)
Age ≥ 80 yr	0.75 ± 1.28	0.48 ± 0.89	–0.27 (–0.63 to 0.08)
Female sex	0.63 ± 1.11	0.50 ± 0.97	–0.13 (–0.47 to 0.20)
≥ 8 medications on best-possible medication history	1.09 ± 1.41	0.24 ± 0.50	–0.84 (–1.16 to –0.53)
Prepopulated medication reconciliation form	0.55 ± 1.05	0.75 ± 0.89	0.20 (–0.55 to 0.94)
Cognitive impairment	1.31 ± 1.84	0.49 ± 0.91	–0.81 (–1.40 to –0.23)
Error of commission			
Nighttime admission (after 8 pm)	0.20 ± 0.46	0.17 ± 0.46	–0.03 (–0.20 to 0.14)
Length of stay ≥ 48 hr	0.17 ± 0.45	0.23 ± 0.60	0.06 (–0.21 to 0.32)
Age ≥ 80 yr	0.21 ± 0.50	0.17 ± 0.44	–0.04 (–0.20 to 0.12)
Female sex	0.24 ± 0.55	0.13 ± 0.37	–0.11 (–0.26 to 0.03)
≥ 8 medications on best-possible medication history	0.28 ± 0.56	0.12 ± 0.38	–0.16 (–0.32 to –0.01)
Prepopulated medication reconciliation form	0.18 ± 0.47	0.13 ± 0.35	–0.06 (–0.39 to 0.28)
Cognitive impairment	0.15 ± 0.38	0.18 ± 0.47	0.03 (–0.24 to 0.29)

Note: CI = confidence interval, SD = standard deviation.

Table 6: Univariate and multivariate associations of patient characteristics with medication discrepancies or errors of commission

Characteristic	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*
Age ≥ 80 yr	1.64 (0.82–3.29)	1.14 (0.50–2.64)
Female sex	1.52 (0.79–2.93)	1.52 (0.74–3.12)
≥ 8 medications on best possible medication history	5.00 (2.45–10.17)	5.05 (2.44–10.46)
Cognitive impairment	2.64 (0.82–8.52)	2.29 (0.55–9.58)
Medication history not verified	0.84 (0.42–1.70	1.10 (0.49–2.44)

Note: CI = confidence interval, OR = odds ratio.
*Adjusted for age, sex, cognitive impairment, ≥ 8 medications on best-possible medication history and not having a medication history completed.

by a research pharmacist as our gold standard, in many cases this information was obtained when the patient was ill, and it is possible that errors occurred during this process. This study was conducted at a large teaching hospital, and the findings may not be generalizable to community settings. Finally, medication discrepancies and errors of commission may result from different patient and/or hospital factors and should therefore be investigated separately in future studies with larger samples.

Conclusion

Despite the implementation of a medication reconciliation process informed by electronic medication dispensing data, clinically relevant medication errors were common in our study. We documented clinically significant errors of commission due to reordering medications that had previously been stopped and continuing medications that had the potential to cause harm. Currently, electronic medication dispensing databases do not contain discontinuation orders, which is an important omission. Prospective comparative studies are needed to evaluate the impact of prepopulating medication reconciliation forms with electronic medication dispensing data on various types of error, particularly on errors of commission that are clinically significant. Our results highlight that the availability of medication dispensing data to inform medication reconciliation does not negate the need to conduct and document a thorough best-possible medication history. Future research is needed to identify patients who are at the highest risk for the occurrence of medication discrepancies and errors of commission in order

to optimize our use of scarce pharmacist resources in medication reconciliation processes.

References

1. Cornish PL, Knowles SR, Marchesano R, et al. Unintended medication discrepancies at the time of hospital admission. *Arch Intern Med* 2005;165:424-9.
2. Kalb K, Shalansky S, Legal M, et al. Unintended medication discrepancies associated with reliance on prescription databases for medication reconciliation on admission to a general medical ward. *Can J Hosp Pharm* 2009;62:284-9.
3. Mueller SK, Sponsler KC, Kripalani S, et al. Hospital-based medication reconciliation practices: a systematic review. *Arch Intern Med* 2012;172:1057-69.
4. Classen DC, Pestotnik SL, Evans RS, et al. Adverse drug events in hospitalized patients. Excess length of stay, extra costs, and attributable mortality. *JAMA* 1997;277:301-6.
5. Tam VC, Knowles SR, Cornish PL, et al. Frequency, type and clinical importance of medication history errors at admission to hospital: a systematic review. *CMAJ* 2005;173:510-5.
6. Quélennec B, Beretz L, Paya D, et al. Potential clinical impact of medication discrepancies at hospital admission. *Eur J Intern Med* 2013;24:530-5.
7. Accreditation Canada/Canadian Institute for Health Information/Canadian Patient Safety Institute/Institute for Safe Medication Practices Canada. *Medication reconciliation in Canada: raising the bar — progress to date and the course ahead*. Ottawa: Accreditation Canada; 2012.
8. Agrawal A, Wu WY. Reducing medication errors and improving systems reliability using an electronic medication reconciliation system. *Jt Comm J Qual Patient Saf* 2009;35:106-14.
9. Poole DL, Chainakul JN, Pearson M, et al. Medication reconciliation: a necessity in promoting a safe hospital discharge. *J Healthc Qual* 2006;28:12-9.
10. Boockvar KS, Blum S, Kugler A, et al. Effect of admission medication reconciliation on adverse drug events from admission medication changes. *Arch Intern Med* 2011;171:860-1.
11. Murphy EM, Oxencis CJ, Klauck JA, et al. Medication reconciliation at an academic medical center: implementation of a comprehensive program from admission to discharge. *Am J Health Syst Pharm* 2009;66:2126-31.
12. Schnipper JL, Hamann C, Ndumele CD, et al. Effect of an electronic medication reconciliation application and process redesign on potential adverse drug events: a cluster-randomized trial. *Arch Intern Med* 2009;169:771-80.
13. Schnipper JL, Kirwin JL, Cotugno MC, et al. Role of pharmacist counseling in preventing adverse drug events after hospitalization. *Arch Intern Med* 2006;166:565-71.
14. Mekonnen AB, McLachlan AJ, Brien JAE. Pharmacy-led medication reconciliation programmes at hospital transitions: a systematic review and meta-analysis. *J Clin Pharm Ther* 2016;41:128-44.
15. Meguerditchian AN, Krotneva S, Reidel K, et al. Medication reconciliation at admission and discharge: a time and motion study. *BMC Health Serv Res* 2013;13:485.
16. Pippins JR, Gandhi TK, Hamann C, et al. Classifying and predicting errors of inpatient medication reconciliation. *J Gen Intern Med* 2008;23:1414-22.
17. Gleason KM, McDaniel MR, Feinglass J, et al. Results of the Medications At Transitions and Clinical Handoffs (MATCH) study: an analysis of medication reconciliation errors and risk factors at hospital admission. *J Gen Intern Med* 2010;25:441-7.
18. Wanbon R, Lyder C, Villeneuve E, et al. Medication reconciliation practices in Canadian emergency departments: a national survey. *Can J Hosp Pharm* 2015;68:202-9.
19. Price M, Bowen M, Lau F, et al. Assessing accuracy of an electronic provincial medication repository. *BMC Med Inform Decis Mak* 2012;12:42.
20. Shalansky S, Jang L, Ignaszewski A, et al. Accuracy of a prescription claims database for medication reconciliation for outpatients with heart failure. *Can J Hosp Pharm* 2007;60:1-8.
21. Hohl CM, Yu E, Hunte GS, et al. Clinical decision rules to improve the detection of adverse drug events in emergency department patients. *Acad Emerg Med* 2012;19:640-9.
22. Fleiss JL. Measuring nominal scale agreement among many raters. *Psychol Bull* 1971;76:378-82.
23. Kwan JL, Lo L, Sampson M, et al. Medication reconciliation during transitions of care as a patient safety strategy: a systematic review. *Ann Intern Med* 2013;158:397-403.
24. Leguelinel-Blache G, Arnaud F, Bouvet S, et al. Impact of admission medication reconciliation performed by clinical pharmacists on medication safety. *Eur J Intern Med* 2014;25:808-14.
25. Alex S, Adenew AB, Arundel C, et al. Medication errors despite using electronic health records: the value of a clinical pharmacist service in reducing discharge-related medication errors. *Qual Manag Health Care* 2016;25:32-7.
26. Shiu JR, Fradette M, Padwal RS, et al. Medication discrepancies associated with a medication reconciliation program and clinical outcomes after hospital discharge. *Pharmacotherapy* 2016;36:415-21.

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