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Electronic medication reconciliation and medication errors

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Abstract

Objective: To measure the impact of electronic medication reconciliation implementation on reports of admission medication reconciliation errors (MREs).
Design: Quality improvement project with time-series design.
Setting: A large, urban, tertiary care children's hospital.
Participants: All admitted patients from 2011 and 2012.
Interventions: Implementation of an electronic medication reconciliation tool for hospital admissions and regular compliance reporting to inpatient units. The tool encourages active reconciliation by displaying the pre-admission medication list and admission medication orders side-by-side.
Main Outcome Measure: Rate of non-intercepted admission MREs identified via a voluntary reporting system.
Results: During the study period, there were 33 070 hospital admissions. The pre-admission medication list was consistently recorded electronically throughout the study period. In the post-intervention period, the use of the electronic medication reconciliation tool increased to 84%. Reports identified 146 admission MREs during the study period, including 95 non-intercepted errors. Pre- to post-intervention, the rate of non-intercepted errors decreased by 53% ($P = 0.02$). Reported errors were categorized as intercepted potential adverse drug events (ADEs) (35%), non-intercepted potential ADEs (42%), minor ADEs (22%) or moderate ADEs (1%). There were no reported MREs that resulted in major or catastrophic ADEs.
Conclusions: We successfully implemented an electronic process for admission medication reconciliation, which was associated with a reduction in reports of non-intercepted admission MREs.

Key words: medical errors, patient safety, adverse events, patient safety, quality improvement, quality management, children, specific populations, hospital care, setting of care

Introduction

It has been nearly 15 years since the Institute of Medicine released To Err is Human, addressing the tens of thousands of patient deaths that occur each year due to medical errors in US hospitals [1]. A more recent analysis suggests the problem is even bigger than suspected, estimating >400 000 patient deaths due to medical errors in the USA each year [2]. Medication errors may account for up to 33% of all hospital errors [3], and unintended medication discrepancies occur in ~33 to 66% of hospital admissions [4–6]. Pediatric patients are particularly vulnerable to medication dosing errors [7–9].

Medication reconciliation is the process of reviewing a patient's medication history, resolving discrepancies and identifying the appropriate list of medications for the patient. Any error in this process represents a medication reconciliation error (MRE). If the error has the potential to cause harm to the patient, it can also be categorized as a potential adverse drug event (ADE). Whether or not the patient experiences an ADE depends on the severity of the error and whether or not it is intercepted before reaching the patient. Performing medication reconciliation at transitions of care is a Joint Commission National Patient Safety goal, as well as an item for the Centers for Medicare and Medicaid Services' Meaningful Use [10, 11]. There is evidence that medication reconciliation can reduce the number of unintended medication discrepancies at transfers of care [12, 13]; however, there are only limited data to suggest that medication reconciliation improves patient outcomes such as ADEs [14] and some evidence to suggest that there is no clinically significant impact [15]. In pediatrics, there are data that show medication reconciliation can be implemented successfully [16, 17], and two studies suggest a resultant decrease in medication errors in neurosurgical patients [18] and transplant patients [19]. However, there remain no data on the impact of medication reconciliation on medication errors across an entire pediatric institution. The frequency and severity of MREs at our hospital was not known prior to this study.

It is possible to have a fully implemented electronic health record (EHR) including computerized prescriber order entry, and documentation systems yet have a suboptimal medication reconciliation process. Medication reconciliation is simply the final step in a multidisciplinary process that starts with an accurate and up to date medication list. For the purposes of admission medication reconciliation, the medication list is often referred to as the pre-admission medication list (PAML). The PAML may be obtained or updated by a nurse, pharmacist, pharmacy technician, appropriately trained healthcare student or prescriber (physician's assistant, nurse practitioner or physician). The admission medication reconciliation as a cognitive process may be performed by multiple members of the team but the final accountability is with the admitting prescriber.

At our institution, the PAML is entered into the EHR by an ED pharmacist, pharmacy technician or trained pharmacy student, or by the admitting nurse. The process of recording the PAML did not change as part of our study intervention. Prior to our intervention, there was an expectation that the admitting provider performs a thoughtful review of a patient's medication list prior to writing admission orders. Admission-order templates included a required field for prescribers to attest as to whether or not medication reconciliation was completed; however, this self-reporting of reconciliation completion did not ensure that the electronic version of the PAML had been reviewed. To review the PAML required navigation to a separate page in the EHR and there was no ability to track this review. We changed admission medication reconciliation to an active, structured process within the EHR where each item on the PAML is affirmed or suspended on a dedicated reconciliation screen. By examining the rates of reported MREs and ADEs, we sought to evaluate the impact of the newly implemented medication reconciliation process.

Methods

Setting

The intervention occurred at a large, urban, academic, tertiary care children's hospital. The hospital began using computerized physician order entry in 2007.

Implementing electronic medication reconciliation

Implementation planning

As part of a quality improvement project, a medication reconciliation committee was formed to oversee the implementation of an electronic medication reconciliation tool within the EHR. The committee consisted of a core group of physicians, nurses, information technology specialists and pharmacists. The existing process for medication reconciliation was reviewed, including the process for nursing and pharmacy to document the patient's PAML. This documentation included updating any existing medications in the EHR, as well as adding and removing medications from the list based on discussion with the patient and family, review of the medical record and occasionally discussion with the patient's community pharmacy. Configuration of the medication reconciliation tool and recommended workflows were developed by consensus of the medication reconciliation committee. Educational materials were created including handouts and a web-based training module.

The electronic medication reconciliation tool available within our EHR consists of a split screen, with the PAML on the left side of the screen (Fig. 1 and Supplementary material, Appendix A). The user may choose whether or not to continue each existing medication. Continued medications are converted to inpatient orders and appear on the right side of the screen. Medications that are not continued remain on the patient's home medication list but do not convert to inpatient orders. Additional medication orders can be added such that the ultimate list of the patient's admission medication orders all appear on the right side of the screen.

Implementation

We introduced the admission electronic medication reconciliation tool by piloting it on one medical service in November 2011. Physicians and nurse practitioners on the medical team received one-on-one instruction on the purpose and process of medication reconciliation. Prior to the pilot implementation providers typically reviewed the patient's medication list in the EHR as well as with the patient and family. In some circumstances, a provider might also contact the patient's primary care provider or community pharmacy to clarify a medication or dose. This process was not altered as part of our implementation. Providers were trained on the use of the medication reconciliation tool and were provided electronic documents with step-by-step instructions. During this pilot phase, pharmacists reviewed each instance of medication reconciliation to ensure that the PAML was accurate, all medications were reconciled and the admission orders reflected the intention of the provider based on their admission documentation. User feedback allowed for fine-tuning of educational materials and development of a recommended workflow, including timely documentation of the PAML in the EHR, and medication reconciliation by the admitting prescriber when writing admission orders. The new medication reconciliation process was then introduced service by service over the next 6 months. Each inpatient service identified a medication reconciliation champion who received additional training and helped

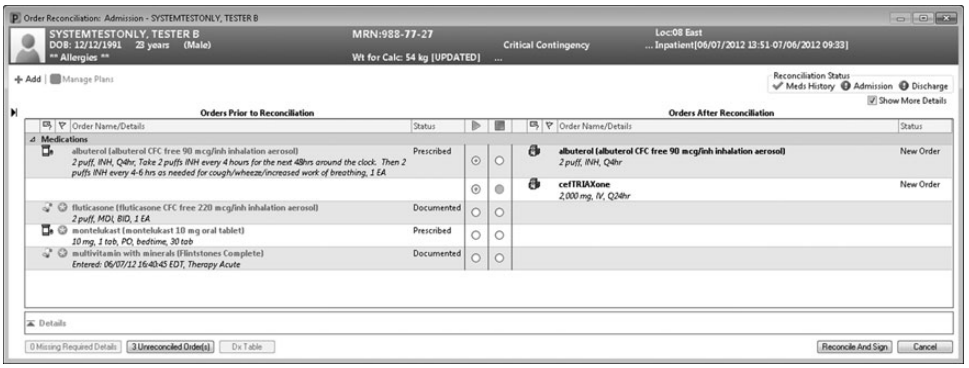

Figure 1 Sample screenshot of electronic medication reconciliation tool. Reproduced with permission from Cerner Corporation©.

Table 1 Safety event reporting system

SERS level	Error type/severity	Description
0	Intercepted potential ADE	Event was intercepted before reaching the patient
1	Non-intercepted potential ADE	Event reached the patient but no change in condition, may have required monitoring to assess for potential change in condition, no intervention indicated
2	Minor ADE	Event reached the patient with transient change in condition, not life threatening, condition returns to baseline, required monitoring, required minor intervention such as holding a medication, obtaining lab test(s), application of heat or cold
3	Moderate ADE	Event reached the patient with transient change in condition, may be life threatening if not treated, condition returns to baseline, required monitoring, required intervention such as reversal agent, additional medication or transfer to intensive care unit
4	Major ADE	Event reached the patient with change in condition, life threatening if not treated, change in condition may be permanent, may have required initial or readmit to hospital, may have required transfer to intensive care unit, required monitoring, required major intervention such as invasive procedure, intubation, hemodynamic support or blood product transfusion
5	Catastrophic ADE	Event reached the patient resulting in patient death

train other team members. In addition, each patient unit identified a local champion, who helped ensure all newly admitted patients had the PAML and medication reconciliation completed promptly upon admission. By June 2012, all medical and surgical services were expected to use the electronic medication reconciliation tool for all hospital admissions. Training materials were made available to all prescribers, and additional one-on-one and group training was provided by request. Training emphasized the importance of medication reconciliation becoming a normative behavior to promote patient safety, and not an additional task to be completed. Along those lines, no incentive or punishment were tied to performance.

Reporting tools

A reporting tool was developed to track daily admission medication reconciliation performance. This report included the name of each patient admitted over the previous 24 h, along with their medical record number, date and time of admission, and whether or not the PAML and medication reconciliation were completed. Starting in July 2012, the report was distributed to the medication reconciliation champion on each inpatient unit, who notified the appropriate providers to complete outstanding PAMLs and medication reconciliations. In addition, a monthly report of electronic medication reconciliation compliance for each department was distributed to medication reconciliation champions and inpatient hospital leadership. Medication reconciliation champions provided feedback on impediments to medication reconciliation completion and additional training and resources were provided as needed.

Evaluation

The medication reconciliation committee tracked adoption of the electronic tool using the monthly medication reconciliation report and through discussion with the local champions.

Safety Event Reporting System

Medication errors were identified using a Safety Event Reporting System (SERS), which has been in place at our institution since 2006, with data tracking back to 2005. There are ~6500 safety event reports filed each year, including 1200 medication error reports per year. The SERS is a voluntary reporting system available to all staff via a web-based module with direct links available on every computer desktop. Safety events are rated on a scale of 0 to 5 (Table 1).

Reported events are triaged, and all medication events are reviewed by a member of the pharmacy staff. The reviewers categorize medication events by type and severity and identify contributing factors. These reviewers routinely score whether the events were related in any way to failures in the medication reconciliation process. All safety events are reviewed regularly and serious events (SERS levels 3, 4 and 5) reported to hospital leadership.

Medication reconciliation errors

In order to identify medication errors related to medication reconciliation, we queried our SERS database for all reported medication safety events for January 2011 through December 2012. We subsequently identified the subset of reported medication safety events that were

identified as related to admission medication reconciliation. Because the relationship between reported safety events and MREs was not always one-to-one, we conducted chart reviews to confirm the number of medication errors in each reported event. MREs were defined as any unintended discrepancy between the patient's home medication regimen and their inpatient medication orders (see Supplementary material, Appendix B for sample MREs). When the etiology of the error was difficult to ascertain, the case was reviewed by the authors blinded to the time period of the event and a decision of whether to include the error was made by consensus. Because our medication reconciliation tool was designed for use by inpatient admitting providers, we excluded errors from non-inpatient areas including the Emergency Department, ambulatory clinics, our ambulatory infusion center, the operating room and the post-anesthesia care unit. We also excluded transfer and discharge reconciliation errors that would not be detected by our admission reconciliation tool, errors that occurred during EHR downtime when the medication reconciliation tool was not available, adverse drug reactions, safety event reports where no error occurred, duplicate reports and reports related to other processes in the medication ordering and delivery system such as allergy history errors, order entry errors and medication administration errors (Fig. 2).

The number of medication safety events that were not related to medication reconciliation was calculated by subtracting the number of medication reconciliation SERS reports from the total number of medication SERS reports.

Analysis

We used a run chart to track adoption of our electronic medication reconciliation tool along with electronic documentation of the PAML. A statistical process control chart [20] was used to track MREs. Because statistical process control charts can detect small process variations, we chose to include the pilot and initial rollout in the post-intervention phase of the analysis. We defined the pre-intervention phase from January 2011 through October 2011 and the post-intervention phase from November 2011 through December 2012. Control limits were set at ±3 sigma and adjusted during the post-intervention period based on special cause variation, defined as: (i) any point beyond the upper or lower control limits (UCL, LCL); (ii) any two out of three consecutive points beyond two sigma from the centerline; (iii) any four out of five consecutive points beyond one sigma from the centerline or (iv) any eight consecutive points above or below the centerline. We used Poisson regression to compare the rate of reported, non-intercepted admission MREs per 1000 admissions pre- and post-intervention. To assess for secular trend unrelated to the intervention, we similarly compared the rate of medication safety events not related to medication reconciliation pre- and post-intervention.

Relative risk of ADEs was determined by comparing the number of all severity ADEs in the post-intervention period/number of admissions in the post-intervention period relative to the number of all severity ADEs in the pre-intervention period/number of admissions in the pre-intervention period.

Safety events were categorized as related to medication reconciliation by one of two pharmacists. A random sample of 10% of safety events were reviewed by both pharmacists, and a kappa statistic was calculated to assess for inter-reviewer agreement.

Results

Adoption of electronic medication reconciliation tool

Use of the admission medication reconciliation tool during the study period steadily increased to 83.8% of admissions (Fig. 3). Electronic documentation of the PAML on admission remained stable at a high level (Fig. 3).

Medication reconciliation errors

Between January 2011 and December 2012, there were 33 070 inpatient hospital admissions. During this time, 1816 medication safety events were reported, including 153 events related to medication

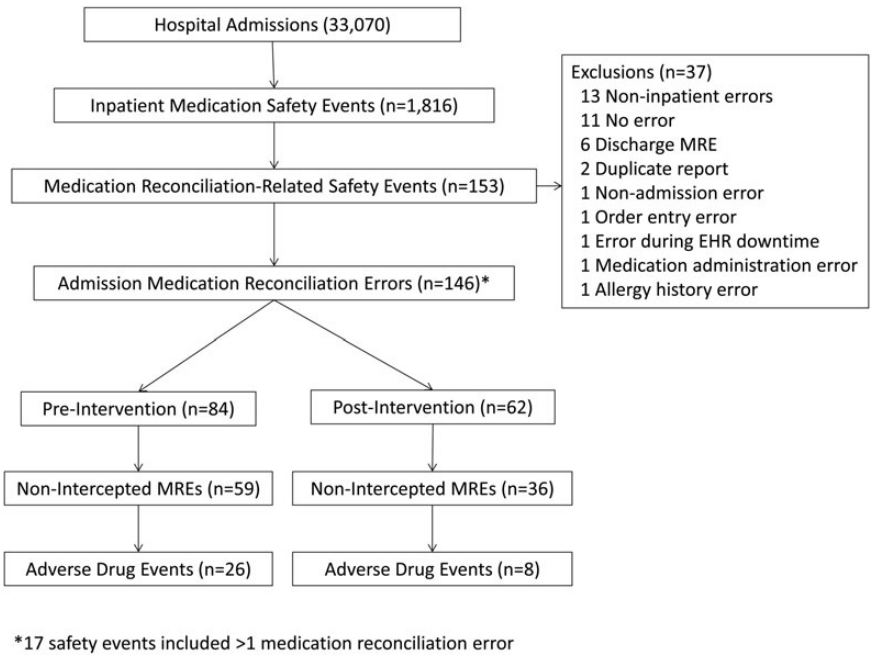

Figure 2 Identification of MREs and ADEs between January 2011 and December 2012.

reconciliation. Of these, 37 events were excluded based on our exclusion criteria. Of the remaining medication reconciliation-related safety events, 17 included >1 medication error. In total, reports identified 146 admission MREs, including 95 non-intercepted MREs and 34 ADEs (Fig. 2).

There were 59 non-intercepted MREs in the pre-intervention period (4.1 errors per 1000 admissions) versus 36 in the post-intervention period (2.0 errors per 1000 admissions). Figure 4 shows the control chart for reported, non-intercepted admission MREs per 1000 admissions and demonstrates a downward shift in the centerline in the post-intervention period. Poisson regression revealed a 53% decrease in the rate of non-intercepted errors post-intervention ($P = 0.02$; 95% CI 26–87%). The rate of medication safety events not related to medication reconciliation did not change significantly post-intervention ($P = 0.41$; 95% CI 81–109%).

The risk of a reported ADE related to admission medication reconciliation in the post-intervention period was significantly lower than that in the pre-intervention period (RR 0.24; $P < 0.001$; 95% CI 0.11–0.53). The kappa statistic for agreement between our two reviewers for classification of SERS reports was 0.76 (95% CI 0.59–0.93).

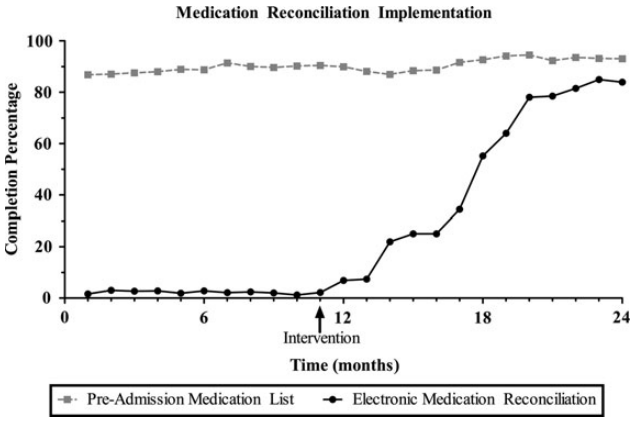

Figure 3 Percent of patients admitted between January 2011 and December 2012 for whom electronic medication history (black circles) and electronic medication reconciliation (gray boxes) were completed.

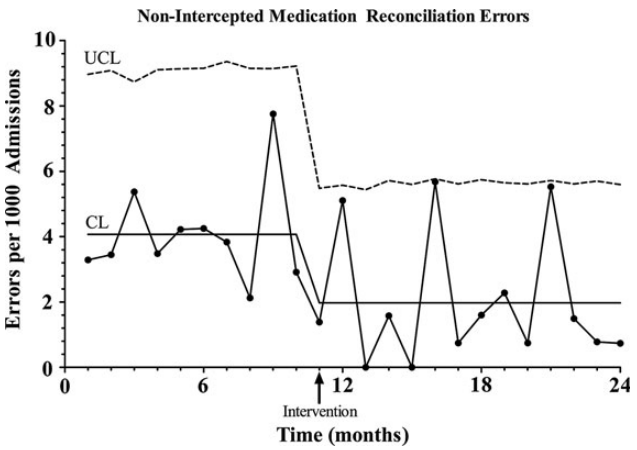

Figure 4 Control chart showing the rate of MREs per 1000 admissions from January 2011 through December 2012. The solid line represents the mean (center line, CL), and the dashed line represents the upper control limit (UCL). The lower control limit was less than zero throughout the study period. Control limits were calculated during the pre-intervention period and adjusted based on special cause variation, as indicated by the downward shift in the mean.

Severity of medication reconciliation errors

The rates of MREs per 1000 admissions stratified by error severity are displayed in Table 2. It can be seen that 35% were intercepted potential ADEs, 42% non-intercepted potential ADEs, 22% mild ADEs and 2 errors (1%) were moderate ADEs. There were no major or catastrophic ADEs related to medication reconciliation in our sample.

Discussion

We successfully implemented an electronic process for medication reconciliation on admission to the hospital and identified a statistically significant decrease in reported, non-intercepted admission MREs after implementation. Likewise, we demonstrate a reduction in the risk of reported ADEs related to admission medication reconciliation post-implementation. Importantly, when we subtracted out medication reconciliation-related errors, there was no significant change in the rate of the remaining medication errors reported during the study period, suggesting that our findings are not simply due to a decrease in overall medication error reporting.

Previous studies have demonstrated that improving medication reconciliation decreases the number of unintended medication discrepancies at transfer of care [12, 13]. Our study supports these findings and adds to this literature as the first large-scale pediatric study evaluating the impact of medication reconciliation process implementation on medication errors and ADEs. Pediatric care presents a unique challenge to medication reconciliation due to the complexity of weight-based dosing, variety of prescription formulations and frequently the involvement of a proxy (parent) when obtaining the medication history.

A systematic review by Mueller *et al.* emphasized the link between pharmacist-related medication reconciliation interventions and decreased preventable ADEs in adults [12]. At our hospital, pharmacists were already involved in medication reconciliation prior to the intervention, so the decrease in reported errors is independent of pharmacist involvement.

Like in previous studies, most of the MREs we identified were of low severity [15]. About three-quarters of admission MREs reported during our study did not result in an ADE. There were only two patients with moderate severity ADEs and no major or catastrophic

Table 2 Severity of reported admission medication reconciliation errors

	Medication reconciliation errors per 1000 admits (*n*)				Total admissions
	Intercepted potential ADEs	Non-intercepted potential ADEs	Minor ADEs	Moderate ADEs	
Study period					
Pre-intervention	1.7 (25)	2.3 (33)	1.7 (25)	0.1 (1)	14 425
Post-intervention	1.4 (26)	1.5 (28)	0.4 (7)	0.1 (1)	18 645
Percentage of total errors (*n*)	35 (51)	42 (61)	22 (32)	1 (2)	

medication reconciliation-related ADEs. While higher severity errors may also be reduced with careful medication reconciliation, we did not have sufficient numbers of severe errors to detect a change.

Our study has some limitations. The major limitation is that medication errors were detected by a voluntary error reporting system, which likely significantly underestimates the true rate of errors and especially intercepted errors. This was not a controlled study, so there is no way to measure the impact of the intervention on the tendency of clinicians to report errors. Selection bias may have led to a change in the way errors were reported in the post-intervention period. Increased awareness of the medication reconciliation process may have led to increased reporting of errors. Alternatively, reporting of errors may have been decreased due to a desire to please administration. Blinded studies using trigger tools might more accurately estimate the rate of MREs in the future. Trigger tools could also help identify intercepted MREs and better understand the effects of the medication reconciliation tool. With this study methodology, it is also impossible to separately consider the impact of our intervention versus other concurrent efforts on reconciliation errors or error reporting. There were other quality improvement initiatives ongoing at our hospital during the time studied though none that directly addressed admission medication reconciliation. Finally, this study was solely focused on inpatient admission medication reconciliation. We therefore cannot speak to the effects of medication reconciliation on hospital discharge or outpatient medication errors.

Our findings suggest a benefit to the implementation of medication reconciliation systems to reduce medication errors for pediatric hospital admissions. A successful medication reconciliation system should include a single source for multidisciplinary medication history review, medication reconciliation that prompts action relating to all home medications and a systematic approach to ensure medication reconciliation is performed for all admissions. Though we have limited data on patient outcomes, our results suggest there are systematic issues with admission medication reconciliation that put patients at risk of medication errors and that further investigation is warranted. Future studies with larger numbers of detected errors are needed to better characterize the impact of MREs on pediatric patient outcomes. In addition, blinded studies using trigger tools or random chart reviews to identify MREs could more accurately estimate the impact of implementing electronic medication reconciliation processes. Larger studies may also help identify whether efforts for admission medication reconciliation can be successfully targeted to a smaller group of patients identified to be at increased risk.

Supplementary material

Supplementary material is available at *INTQHC* online.

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