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Implementation of a Medication Reconciliation Risk Stratification Tool Integrated within an electronic health record: A Case Series of Three Academic Medical Centers

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ABSTRACT

Medication errors during transitions of care are common, dangerous and costly. Medication reconciliation can help mitigate this risk, but it is a complex and time-consuming process when performed properly. Increasingly, pharmacy staff have been engaged to help improve medication reconciliation. However, many organizations lack the resources and staff required to perform accurate medication histories and other reconciliation tasks on all patients. We describe how three academic medical centers implemented risk scoring systems to allocate limited pharmacy resources to patients with the highest likelihood of medication reconciliation related errors. We found that (1) development of a tailored medication risk scoring system and integration into the electronic health record is feasible, (2) workflow around the risk calculator is critical to the success of the implementation, and (3) the complex coordination of professional disciplines during the medication reconciliation process remains an ongoing challenge at all three institutions.

1. Background

Medication errors occur frequently at transitions of care and lead to significant patient harm and healthcare expense.[1,2] Robust medication reconciliation practices can mitigate these errors, but this process is complex and time-consuming.[3] Due to these and other barriers, few institutions have been able to sustain high-quality and reliable medication reconciliation processes. The Multi-center Medication Reconciliation Quality Improvement Study (MARQUIS) sought to establish and disseminate best practices for medication reconciliation and to create tools that could readily be adopted in a variety of healthcare settings.[4–8] MARQUIS2 is a multi-center study to further develop and implement best practices based on the lessons learned from the first MARQUIS study.[9] Here, we report the efforts of three academic medical centers (AMCs) that participated in the MARQUIS2 study.

Medication reconciliation on admission consists of obtaining an accurate prior to admission (PTA) medication list by taking a "best possible medication history" (BPMH).[10] Medications should be verified (developing an accurate list of medications), clarified (validating dose, route, frequency and time of last administration at the time of ordering medications), and then reconciled. Reconciliation is the process of identifying and correcting unintentional discrepancies, documenting intentional medication changes, and communicating an accurate medication list to the next provider(s).[11] One of the conclusions of

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MARQUIS was that pharmacist involvement in medication reconciliation, particularly with regards to obtaining a BPMH, is a key component to improving the reliability of the process.[12] In practice, health care organizations often do not have the resources to staff the number of pharmacy team members required to provide high-quality medication reconciliation to all patients.[13]

Prior to MARQUIS2, medication reconciliation was a fragmented, poorly integrated process at our three AMCs. Role clarity between physicians, pharmacy staff and nursing staff was lacking. Moreover, within physician, pharmacy and nursing teams, communication and teamwork were deficient (e.g., regarding what medication reconciliation tasks had been done, the quality of that work, and what tasks still needed to be completed and by whom). Due to evidence that pharmacists perform more accurate and thorough medication histories,[14–17] pharmacists or pharmacy technicians were tasked to play an increasing role in obtaining the BPMH. However, the 25 min needed on average for a high-quality medication history[16,17] quickly consumed the limited time resources of each of our AMC's pharmacy teams who were unable to complete the BPMH on all eligible patients, leading each AMC to seek an efficient and reliable method to best leverage their pharmacy teams' capacities. We describe the efforts of AMCs, as part of the MARQUIS2 collaborative, to develop such systems within a commonly available EHR.

2. Context and problem

Our three AMCs are each large, tertiary care hospitals (Table 1) that act as both safety net and referral centers for their respective regions. At all three sites, before the MARQUIS2 study, medication reconciliation was initially seen primarily as a physician function, traditionally performed by medical students and residents. Also, in each of our three AMCs, pharmacy staff gathered the PTA medication list on a few patients perceived as high risk. Determination of 'high risk' varied and was left to the clinical judgement of each pharmacist. Through participation in MARQUIS2, pharmacists and pharmacy technicians at each AMC were deployed to improve medication reconciliation accuracy and safety, redefining teams and roles (Table 2). At AMC-1, pharmacy staff involved in obtaining the BPMH included both pharmacists and pharmacy technicians, while at the other two, pharmacy technicians were not used for medication history-taking.

All three AMCs use Epic as the integrated EHR spanning inpatient and outpatient care within their health systems. Additionally, safety reports of multiple adverse medication events were traced back to medication reconciliation errors at all the sites. These events led to patient harm, increased costs and operational inefficiencies such as increased length of stay and readmissions. Those events, coupled with Joint Commission guidance for improved medication reconciliation processes as a National Patient Safety Goal,[18,19] engaged the sites from "*C*-suite" leadership to front-line staff.

At AMC-1, prior to joining MARQUIS2, the ED pharmacy technician used a combination of subjective and objective patient-specific information to prioritize medication history-taking. To determine if a patient was a high-risk candidate for medication history-taking, the pharmacy technician reviewed the patient's presentation and patient's Emergency Severity Index (ESI score),[20] which is automatically generated in the EHR for every ED patient. Staff soon realized that the ESI score was not a good objective measure because it was developed to determine likelihood of admission, not risk for medication reconciliation errors or potential harm from these errors. AMC-1 considered using a medication-focused risk tool that had been implemented into their EHR to help prioritize discharge education.[21] However, the tool was meant for patients who were already admitted, with scores including medications ordered in the hospital. As AMC-1 joined MARQUIS2, the question of how to incorporate a medication-focused risk tool to guide pharmacy technicians' efforts in the ED was still unanswered.

At AMC-2, the medication reconciliation process often included redundant work. Commonly, a physician or advanced practice provider would admit a patient, performing a medication history in order to write admission orders, then a pharmacist would perform a detailed medication history and contact the provider to add, change or discontinue medications that had been ordered in error. For some patients admitted through the ED, pharmacists stationed in the ED started the medication history. This was often incomplete by the time of admission and the patient was transferred to the floor with no formal handoff between ED pharmacists and floor pharmacists. Additionally, this AMC did not have a formal priority system to help pharmacists identify patients at highest risk of medication reconciliation errors. Both the ED pharmacist and floor pharmacists chose patients to evaluate based on perceived need and time availability.

AMC-3 faced similar problems. Additionally, patients experienced frequent handoffs during the hospitalization, a lack of clear responsibility and ownership for the medication reconciliation process, and constant conflict between the time allocated and the time needed to perform a proper medication history.

Table 1
Academic medical center demographics.

	AMC-1	AMC-2	AMC-3
Beds	390	576	996
Region	West	Northwest	Southeast
Trauma Center Level	One	One	One
Operating Budget	$2.0B	$3.5B	$5.6B
Employees	17,000	19,000	22,000
Faculty	1,700	2,500	8,000
Admissions Requiring BPMH/Day[a]	57	72	20
Pharmacy BPMH Capacity/Day[a] (N,%)	9 (16%)	25 (35%)	4 (20%)

[a] For intervention units only.

3. Solution

3.1. AMC-1

3.1.1. Risk stratification tool development

In response to the issues noted above, the team implemented a medication risk stratification tool within the EHR. Their pharmacists and pharmacy technicians could quickly identify all patients with scores above pre-specified thresholds. As the tool had initially been developed to stratify discharge medication risk, as part of MARQUIS2, it was modified to account for fields that were typically available at the time of patient presentation to the ED, e.g. removing criteria based on admission orders (Table 3). Thresholds for risk stratification were modified downwards from the established discharge thresholds to account for the lesser number of data elements that were available when patients were in the ED.

3.1.2. Tool implementation and workflows

The ED-based pharmacy technician prioritized medication histories for patients into categories as follows: 1) ED patients being admitted and with a moderate or high-risk score; 2) patients who were admitted overnight with a high-risk score; 3) ED patients with a high-risk score regardless of admission status; and finally, 4) ED patients with no home medications recorded in their EHR profile, suggesting that the patients were from out of system and would not have a valid risk score. In developing this workflow, UCSD refined their thresholds for moderate and high-risk patients based on historical data to match pharmacy team capacity to perform medication histories - about 8–10 medication histories per pharmacy technician per 8-h shift.

To alert admitting physicians as to which patients pharmacists had targeted for medication reconciliation, a new medication list status category was created to identify those patients in the process of undergoing a pharmacist technician's BPMH.[22]

Table 2
Teamwork role transformation and clarification.

Key Medication Reconciliation Roles	Pre-Implementatio High & Non-High Risk			Post-ImplementationNon-High Risk High Risk					
	AMC-1	**AMC-2**	**AMC-3**	**AMC-1**	**AMC-2**	**AMC-3**	**AMC-1**	**AMC-2**	**AMC-3**
Verification	MD, pharmacy tech	MD, RN, pharmacist	RN, pharmacist	MD	MD, RN, pharmacist	RN	pharmacy tech	pharmacist	pharmacist
Clarification	MD, pharmacy tech	MD, RN, pharmacist	RN, pharmacist	MD	MD, RN, pharmacist	RN	pharmacy tech	pharmacist	pharmacist
Reconciliation	MD	MD with pharmacy review	MD	MD	MD with pharmacy review	MD	MD with pharmacy review	MD with pharmacy review	MD with pharmacy review

Table 3
Risk stratification tool parameters.

Parameters	AMC-1/AMC-2 (1 point per parameter met)	AMC-3 (10 points per parameter met)
1	Age 65 or greater	Age 75 or greater
2	>/ = 8 medications on outpatient medication list	>/ = 10 medications on the outpatient list
3	Admitted from a Long-Term Care Facility, Residential Care, Skilled Nursing Facility, Intermediate Care or Rehab Facility	High-risk medications (anticoagulants, antiretrovirals, insulin)
4	ED visits in the past 180 days, 1 point per visit, maximum 4	–
5	Readmissions in the past 180 days, 1 point per visit, maximum 4	Readmission within 30 days.
6	CrCl <30 mL/min in the past 3 days	–
7	Outpatient order for an IV medication	–
8	Problem of CHF	CHF, AMI or ESRD
9	Problem of COPD	–
10	Problem of AIDS	–
11	Problem of Acute MI	–
12	Problem of Intermittent Hemodialysis (AMC-1) or ESRD (AMC-2)	–
Total Possible	18 points	50 points
Low Risk	<4 (AMC-1) <6 (AMC-2)	<30
Moderate Risk	4 - 7 (AMC-1) N/A (AMC-2)	N/A
High Risk	>7 (AMC-1) >6–10 (AMC-2)*	>/ = 30

** Parameters in Epic discharge risk stratification tool not used for admission risk stratification for AMC-1 and AMC-2: If the patient's home medication list has not been marked as reviewed since admission. Length of stay is > 5 days. Discharged to Long-Term Care Facility, Residential Care, Skilled Nursing Facility, Intermediate Care or Rehab Discharge medications have been updated since discharge paperwork was last printed. Anticonvulsant on patient's outpatient or inpatient medication list. Antiretroviral on patient's outpatient or inpatient medication list. Long-acting opioid on patient's outpatient or inpatient medication list. Transplant medication (AMC-1) or immunosuppressive (AMC-2) on patient's outpatient or inpatient medication list.

* Depending on unit and pharmacy coverage.

3.1.3. Evaluation and evolution

AMC-1 established an on-going measurement system including the number of patients reached, the number of medications reviewed, the percentage of medications changed, the number of patients with high-risk medications, the number of high-risk medications and the percentage of high-risk medications changed (Table 4). Key success factors for this effort were having dedicated pharmacists on both the "transitions of care" and EHR development teams. This enabled the organization to develop the medication-focused risk tool and further change the workflow centered around the tool. Several iterations of the workflow algorithm were required to balance the quantity of medications on a patient list with the presence of high-risk medications. In the end, AMC-1 found high-risk medications to have more influence on the algorithm then the absolute number of medications.

Table 4
AMC-1 pharmacy staff effectiveness.

Category	Pre-MARQUIS2	Post-MARQUIS2	p-value
Patients seen per month (Mean, SD)	111.7 (16.7)	101.0 (26.1)	0.401
Medications reconciled/patient (Mean, SD)	11.9 (0.9)	16.7 (1.4)	0.001
Patients requiring change (any medication) (N, %)	911 (90.7%)	564 (93.1%)	0.090
Patients with high-risk medications[a] (N, %)	664 (66.1%)	490 (80.9%)	0.001
Patients with changes to high-risk medication (N, %)	499 (75.2%)	361 (73.7%)	0.569

[a] High risk medications: anticoagulants, antiplatelets, hypoglycemics, opioids, antiepileptic, sedatives, and psychotropics.

3.2. AMC-2

3.2.1. Risk stratification tool development

AMC-2, as part of the second wave of MARQUIS2 sites (starting four months after the first wave, which included AMC-1), decided to adopt the risk stratification scoring framework from AMC-1's successful experience. Similarly, the team removed inpatient and discharge-related criteria (e.g. patient discharging on anticoagulation). The pharmacy's technical team then evaluated the ability to identify the criteria in the EHR. For example, "intermittent hemodialysis" was converted into "ESRD" on the problem list screen. If the criterion wasn't identifiable in the patient chart but felt to be important enough, such as "admitted from" and "discharge to" locations, new, discrete data elements and workflows were implemented to document them in the EHR.

3.2.2. Tool implementation and workflows

At AMC-2, pre-intervention, an ED pharmacist typically started the BPMH, with unit-based pharmacists then completing the majority of the BPMH. Without a handoff, this resulted in substantial rework. As a result of MARQUIS2, the ED pharmacists adopted the risk stratification tool to target high risk patients, limiting the number of patients seen while increasing complete BPMHs at time of transfer to the floor. A handoff was developed between ED pharmacists and floor pharmacists when there was an incomplete medication history (e.g., medications needed confirmation from a second source or dosing was still unclear) or when high risk patients were admitted to the floor with no BPMH started in the ED.

As different units had different pharmacy staffing levels, during the pilot period, AMC-2's QI team initially adjusted the scoring threshold daily by which patients were prioritized for obtaining BPMHs according

to the capacity of each unit pharmacist. Accordingly, depending on the unit, each group of pharmacists chose a score threshold, based on pilot period data, which approximated the number of patients at each scoring threshold and average number of patients that could be seen per pharmacist. After pharmacists finished medication reconciliation on the high-risk patients, they attended to their other duties (order verification, antibiotic dosing, renal dosing, monitoring for drug interactions etc.).

3.2.3. Evaluation and evolution

AMC-2 encountered several difficulties with their initial implementation. They found that a few units had significantly reduced medication reconciliation completion rates. A deep dive found high-risk thresholds being set too high and pharmacists prioritizing other clinical tasks once BPMHs on all patients who met the high-risk threshold had been completed. AMC-2 also found that, rather than using the actual risk stratification score as a way to prioritize patients, some pharmacists were only using the functionality that let them see the individual criteria contributing to the score to help them target, based upon their own clinical experience and judgment, the patients they deemed to be highest risk. AMC-2 subsequently moved towards a standard threshold across all units, using the tool as intended, and setting thresholds that balanced medication reconciliation with other duties.

While AMC-1 and AMC-2 implemented a nearly identical technical tool, differing implementation workflows resulted in markedly different outcomes. In allowing more unit-to-unit autonomy in setting thresholds to balance workload and capacity, AMC-2's clinical units found that medication reconciliation clinical productivity decreased substantially as pharmacists favored other duties, perhaps reflecting an overemphasis on autonomy over standardization.

3.3. AMC-3

3.3.1. Risk stratification tool development

Prior to having a scoring tool, pharmacists at AMC-3 randomly targeted a percentage of the patients in the hospital (or in response to individual provider request) to obtain a BPMH and update the PTA med list. To better streamline this process, they sought to identify those patients at highest risk for medication reconciliation-related error and performed a review of the literature to identify risk factors associated with errors related to medication reconciliation.[23–30] A final list of risk factors selected for inclusion in the tool were based on the literature review, an analysis of internally reported medication errors, and availability as discrete data elements in the EHR for use in scoring rules (Table 3). These selected risk factors were then used to create a real-time risk calculator in their EHR. It should be noted that this process resulted in a much shorter list of criteria than at either of the two other AMCs.

3.3.2. Tool implementation and workflows

Rules were built within the EHR to identify patients meeting each risk factor. A score of ten points was assigned for each risk factor. A parent rule flagged patients if their total risk score met or exceeded thirty (i.e. had three or more risk factors), and these patients were presented to pharmacists and pharmacy trainees via a patient list within the EHR. When medication reconciliation was completed or attempted, patients were "marked as reviewed" within the patient list, resulting in a visible change in the flag icon. This allowed for easy identification of the high-risk patients still requiring medication reconciliation. In addition, a "comments" column was available to enter free text notes to communicate key pieces of information to physicians and advanced practice providers.

3.3.3. Evaluation and evolution

After development and implementation of the risk tool, given the limited availability of pharmacy resources and the emphasis on fast patient throughput in the ED, to not delay ED throughput, the AMC-3 QI team decided to pivot their efforts and redeploy the medication reconciliation interventions on two medical-surgical units. The team chose those units based on pharmacy resources and nursing support and targeted the patients admitted from the ED. Within 24 hours of admission, patients were stratified into average risk and high risk based on the risk calculator. If the calculator identified a high-risk patient, a red exclamation point appeared in the patient's medication reconciliation EHR column which could be seen on the pharmacist, nurse and physician's view. After the pharmacist performed the BPMH and updated the PTA med list, the pharmacist double clicked the red exclamation point which then turned green.

As noted, physicians and nursing staff could also add this column to their patient rounding list to see whether the patient was high risk (red) and whether pharmacy had completed the BPMH and PTA updates (green).

On the two implementation units, for non-high-risk patients and for high risk patients that pharmacists were not able to see, nurses had the responsibility for the BMPH and updating the PTA medication list. A dedicated nurse on each of the two implementation units from 10a to 6p performed the BPMH and updated the PTA medication list. Nurses indicated completion of their admission BPMH and PTA list update through a "BPMH is done" icon which could be seen on the admission PTA med list in the admission medication reconciliation navigator.

4. Results

At AMC-1, after implementing the risk score tool and workflow, pharmacy team members performed medication histories on patients with more complex medication regimens. Pre-post analysis revealed that technicians were now taking a BPMH on patients with a higher risk score and on more medications. Additionally, ED pharmacy technicians saw more patients with high-risk medications (Fig. 1 and Table 4). AMC-3, using a different risk stratification tool from AMC-1, experienced similar increases in patients evaluated with higher risk scores and higher risk medications as AMC-1. Although AMC-3s data (not shown) were not as scientifically robust as AMC-1s, the trends towards improvement were satisfactory for operational purposes. AMC-2, using the same risk stratification tool as AMC-1, but a different implementation plan, did not show initial improvements in high-risk patients and medications assessed by pharmacy staff resulting in a redesign of their workflows around the risk stratification tool.

This risk stratification approach has the potential to substantially improve the return on investment (ROI) of medication reconciliation efforts. For example, at AMC-1, with 20,400 admissions per year, the 30-day readmission rate was 36% in the high-risk cohort (without any intervention) and 12% among all patients. The intervention producing even a conservative 6% relative risk reduction in readmission rates,[31,32] and decreasing costs by $9600 per readmission,[33] with a strategy focusing these efforts solely on high risk patients (i.e., by hiring 2.6 pharmacy technicians at a salary of $40,000, taking a BPMH every 48 minutes) would produce an ROI of $919,836. In contrast, using these personnel on a random sample of the same number of patients would produce an ROI of $214,812; a difference of $705,024.

5. Unresolved questions and lessons for the field

We developed and implemented risk stratification tools in Epic at three separate AMCs to better identify high-risk patients and target limited pharmacy resources to patients with the most complex and highest risk medication profiles. An ongoing challenge at all sites is obtaining adequate pharmacy resources to evaluate all high-risk patients instead of using cutoffs. As long as pharmacy staff are unable to perform BPMH for all patients, educating physicians, APPs and RNs in best practices also remains a challenge at all sites. At each of the three sites, role clarity and communication patterns, while improved, are still being optimized. While Epic was used at all three of our sites, all other major EHRs (e.g., Cerner, Allscripts, Meditech) have the capability to

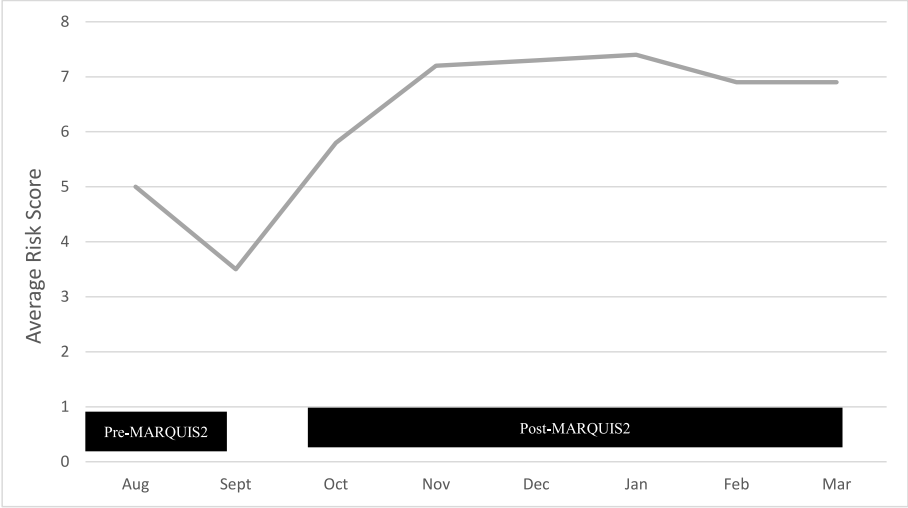

Fig. 1. Risk score of patients with pharmacy driven medication reconciliation, AMC-1 (2016–2017).

program similar changes and contribute the required data to an abstractable enterprise warehouse.

Based on the full results of the MARQUIS2 study,[34] best practice is a pharmacy driven BPMH for all admitted patients. However, as this may not be possible for many hospitals, we demonstrate how risk stratification tools to best leverage limited pharmacy staffing may be developed and implemented into the EHR, resulting in both improved patient care and financial operations. While an identical tool may be employed in multiple institutions, differing workflows built around the tool may produce widely differing results. Workflows that achieve role clarity and emphasize communication and coordination of efforts both within the pharmacy team and between pharmacy staff and other professions are likely to yield the best results.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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