

AHRQ Grant Final Progress Report
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Grant Award Number: R18HS017906

TITLE PAGE

Title of Project: Risk-Informed Intervention to Improve Ambulatory Drug Monitoring and Safety

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Organization: University of Massachusetts Medical School

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STRUCTURED ABSTRACT (maximum of 250 words)

Purpose: To improve patient safety by implementing interventions to improve the rate of ordering and completion of therapeutic laboratory monitoring of high-risk medications in the ambulatory setting.

Scope: Failure to appropriately monitor older patients on drug therapy is among the most frequent causes of preventable adverse drug events in the ambulatory setting; 41% of preventable, serious adverse drug events have been found to be associated with inadequate laboratory monitoring. In a prior study, we found that lack of redundancy and communication problems were the major system factors underlying inadequate monitoring.

Methods: We implemented a series of interventions, including computerized alerts about monitoring to prescribers, telephone and mailed reminders to patients, alerts of overdue lab tests to prescribers and clinic staff, and inclusion of information about ordered laboratory monitoring in the printed information provided to patients and on the patient portal. We estimated the costs associated with each intervention and evaluated the impact on rates of laboratory monitoring.

Results: Analyses of baseline ordering and completion of laboratory monitoring and interviews with patients about missed lab tests provided a basis for the design of the interventions.

However, the impacts of the interventions were small, and most were not statistically significant. Automated alerts generated to prescribers at the time of medication renewals did increase test ordering. Cost estimates for development of the interventions found extensive time required from a physician/informaticist.

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PURPOSE

Our overall goal was to improve patient safety by implementing an intervention directed at improving the rate of ordering and completion of therapeutic laboratory monitoring of high-risk medications in the ambulatory setting. The specific aims of this demonstration project were to:

1. Implement the multipronged intervention
2. Evaluate the impact of the intervention on laboratory monitoring
3. Assess any unexpected consequences for patients, prescribers, and clinic staff
4. Estimate the costs associated with the intervention and the potential return on investment
5. Prepare a toolkit to enable implementation in other ambulatory settings

SCOPE

Adverse drug events, especially those that may be preventable, are among the most serious concerns about medication use in older persons cared for in the ambulatory setting. Among older adults treated in the ambulatory setting, our previous study found an incidence of adverse drug events of 50.1 per 1000 person-years and a rate of preventable adverse drug events of 13.8 per 1000 person-years.¹ Failure to appropriately monitor older patients on drug therapy is among the most frequent causes of preventable adverse drug events in this setting; 41% of preventable, serious adverse drug events were associated with inadequate laboratory monitoring.¹

Laboratory monitoring errors occur when there is failure to conduct the indicated laboratory test, when there is avoidable delay in responding to abnormal tests, or when there is inadequate follow up. Multiple studies document the low prevalence of appropriate monitoring of high-risk medications in the ambulatory setting.²⁻⁶ Efforts to improve laboratory monitoring of high-risk medications have been developed in various clinical settings. In the inpatient setting, automatic orders for laboratory monitoring tests more than doubled physician adherence to recommended testing.⁷ In the outpatient setting, results have been mixed. Improvements in the safe use of medications requires identification of additional effective approaches to increasing therapeutic monitoring of high-risk medications.

In a proactive risk reduction project, we established interdisciplinary risk modeling teams recruited from the staff of a large, multispecialty medical group practice, including clinicians, nurse managers, and pharmacists. The teams brainstormed to build fault trees underlying several types of medical errors. We identified cut sets using PRA software. To identify potential intervention points, we performed qualitative review of the fault trees and cut sets to understand failures in the medication handling process that lead to inadequate laboratory monitoring. We found that the failures were primarily a product of the lack of redundancy and missing communication links.

In this demonstration project, we implemented a multipronged intervention to add redundancy to the Reliant Medical Group's system for medication handling and specifically addressed the missing communication links. The intervention included computerized alerts about monitoring to prescribers, telephone and mailed reminders to patients, alerts of overdue lab tests to prescribers and clinic staff, and inclusion of information about ordered laboratory monitoring in the printed information provided to patients and on the patient portal. We evaluated the impact of the intervention on rates of laboratory monitoring, assessed any unexpected consequences, estimated the costs associated with the intervention, and prepared components of a toolkit to enable implementation in other ambulatory settings. We used an interrupted time-series design to evaluate the impact of each component of the multipronged intervention on the rate of therapeutic laboratory monitoring of high-risk medications.

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Study Site and Setting

This study was conducted in the setting of a large, multispecialty group practice closely aligned with a nonprofit, Central Massachusetts-based health plan. The group practice employs 330 outpatient clinicians, including 250 physicians at 23 ambulatory clinic sites covering 30 specialties. The group provides care to approximately 180,000 individuals, many of whom are members of an associated health plan with which the group practice shares financial risk. During the course of this study, the practice used the EpicCare Ambulatory EMR®, version Summer 2009 IU6.

METHODS

We performed a prospective study, adding a series of interventions to increase ordering and completion of laboratory monitoring for high-risk medications according to guidelines, using time series regression to assess their impact. This included development of guidelines for laboratory monitoring and examination of baseline factors associated with ordering as well as factors associated with patient completion of ordered tests. We also tracked the costs for developing and implementing each intervention and prepared components for a toolkit.

Development of guidelines for laboratory monitoring of high-risk medications.

The development of the monitoring guidelines consisted of a multistep process that included review of existing guidelines; recommendations in the Physicians' Desk Reference (PDR), clinical guidelines, and black box warnings (BBWs); consensus panel review by a national committee; and final review by a local expert panel. The results have been published.⁸

Interviews with patients to support development of communication approaches for improving completion of ordered laboratory monitoring tests.

Using a semi-structured interview format, we interviewed patients to explore their perceptions on noncompletion of laboratory tests. We used a purposive sampling approach to select patients who completed or did not complete a laboratory test ordered for one of the study medications. We contacted and interviewed patients until theme saturation was achieved. Using a grounded theory approach,⁹ two researchers developed codes based on four transcripts (17% of total sample). By the fourth transcript, the research team was confident of coding consistency and moved forward with coding the remaining transcripts.

Baseline ordering of monitoring laboratory tests.

For this analysis, the outcome was ordered status for a monitoring test, dichotomous for each patient-drug-test combination. Predictor variables were provider characteristics, including gender, age, type, primary care provider versus specialist, full-time working status, years of experience, frequency of prescribing a given drug, and number of patients to whom drug was prescribed were included. Other variables analyzed were patient characteristics, including age, gender, number of study prescriptions, and visit frequency, as well as specific diagnoses, including dementia and heart disease, and number of other study medications. The unit of analysis was a prescription-test pair. The outcome was whether an indicated test was ordered (yes/no). Parameter estimates are reported as odds ratios (ORs) of factors associated with test ordering.

Baseline completion of monitoring laboratory tests.

For the second baseline analysis, the key outcome variable was noncompletion by the patient of an ordered test. The unit of analysis was the drug-test pair. We used claims data to identify the first dispensing of one of the study medications prescribed in 2008. Completion of each ordered test was determined by matching the test order with test results based on a unique order identifier. Test ordering was defined as having occurred if there was at least one

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recommended test for the drug-test pair ordered up to 365 days before the index dispensing in 2008 through 14 days after the dispensing, if the test was indicated annually (or 180 days before to 14 days after index dispensing if the test was indicated every 6 months). Patient characteristics included age, gender, number of prescriptions for study medications, and visit frequency. Provider characteristics, including gender, age, and specialist versus primary care status, were also included in the model. Prescription characteristics included the drug, a hierarchical indication for monitoring, whether the drug had single or multiple recommended monitoring tests, and recommended testing frequency. Prescriptions, laboratory orders, and test completion were extracted from the EMR for the study period. To determine which factors were independently associated with laboratory test noncompletion, we used logistic regression models to calculate odds ratios (ORs) of factors associated with test noncompletion.

Multipronged interventions developed and implemented during the study.

A series of HIT-based interventions was implemented through the 4 years of the study. Each of these is illustrated below.

A. Computerized alerts about monitoring to prescribers

1. Automated alerts at the time of medication renewal

63 y.o. female calling with request to renew:
Lisinopril 5mg OR Tabs
Any special requests or concerns?- {Choose only the relevant questions for the specific medication:17063}
When do you need the medication for?- {REFILL TIME NEEDED BY:17062}
Next visit in PCP office: Visit date not found **Last OV in Dept:** 2/23/2011
Allergies: Sulfamethoxazole w-trimethoprim and Macroid

Component	Value	Date
SODIUM	143	2/12/2010
POTASSIUM	4.1	2/12/2010
CHLOR	106	2/12/2010
CO2	25	2/12/2010
BUN	14	2/12/2010
CREATININE	0.67	2/23/2011
GLUCOSE	113*	2/23/2011
CAL	9.7	2/12/2010

An open order for Basic exists.

Testing recommended a minimum of yearly for chronic therapy .

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Based on last lab testing intervals, 1 month of refills suggested for potassium, diuretics, ACE inhibitors and ARBs. Please arrange updated lab monitoring.

2. SmartSet directions for ordering laboratory tests

Select one item from each section. Patient should be fasting if basic or lipid is obtained.

- [Review the chart, remind the patient of any previously ordered items and remove any duplicate orders. \(13205\)](#)
- [Advise patient to have labs drawn at least 2 days prior to appointment. \(13205\)](#)
- [CBC \(Dx: Screening\) \(13166\)](#)
- [CBC \(Dx: Anemia\) \(13169\)](#)
- [CBC \(Dx: Medication monitoring\) \(13441\)](#)
- [Urinalysis \(Dx: Hx hematuria\) \(13189\)](#)
- [Urine Chlamydia \(Dx: Screening\) \(13247\)](#)
- [Fasting Lipid Profile \(Dx: Hyperlipidemia\) \(13170\)](#)
- [AST for antilipid or antiseizure medication use \(Dx: Medication monitoring\) \(13179\)](#)
- [Fasting Lipid Profile \(Dx: Screening\) \(13195\)](#)
- [Basic \(Dx: Screening\) \(13201\)](#)
- [Basic \(Dx: Htn\) \(13200\)](#)
- [Basic due to Digoxin, diuretic or Tegretol use:\(Dx: Medication monitoring\) \(13203\)](#)
- [Digoxin Level \(Dx: Medication monitoring\) \(13183\)](#)
- [Hem A1C \(Dx: Impaired fasting glucose\) \(13249\)](#)
- [Diabetic Labs-Microalbumin \(Dx: Diabetes\) \(13177\)](#)
- [Diabetic Labs-Basic \(Dx: Diabetes\) \(13204\)](#)
- [Diabetic Labs-Lipids if not done in 1 year \(13199\)](#)
- [Diabetic Labs-Hem A1C \(Dx: Diabetes\) \(13191\)](#)
- [PSA: \(Dx: Screening\) \(13180\)](#)
- [Thyroid Cascade \(Dx: Thyroid disorder\) \(13182\)](#)
- [Theophylline level \(Dx: Medication monitoring\) \(13184\)](#)
- [Carbamazepine \(Tegretol\) Level \(Dx: Medication monitoring\) \(13186\)](#)
- [Dilantin Level \(Dx: Medication monitoring\) \(13187\)](#)
- [Phenobarbital Level \(Dx: Medication monitoring\) \(13440\)](#)
- [Depakote Level \(Dx: Medication monitoring\) \(13188\)](#)

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B. Reminders to patients to complete ordered laboratory tests

1. Inclusion of information about ordered labs on summary sheets given to patients after each office visit

Orders	
Future Orders	Expected By
FECAL GLOBIN IMMUNOCHEMICAL TEST (FALLON)	1/20/13
BASIC METABOLIC PANEL WITH (GFR)	12/22/12

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2. Automated telephone reminders

Followed by offers to repeat, and messages for answering machines and human respondents who are not the patient in question.

Outbound Call

Hello, this is XXX's automated appointment reminder service calling to confirm a lab appointment for <first name> <last name>. **Target -** Yes or no, is this <he/she>?

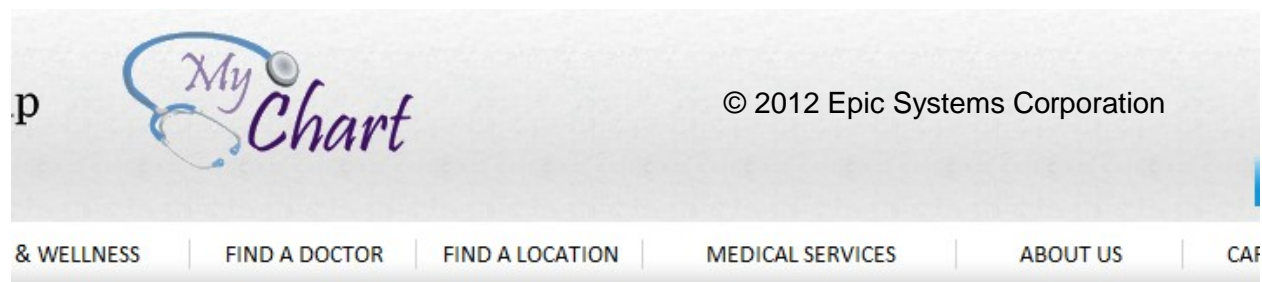
Target:Yes - Great! **[Go_To]** **Content**

[Target:No - **[Go_To]** **Unavailable]**

Content

As you may recall, a XXX Group healthcare provider had ordered a lab test for you. We just want to remind you that this lab test is due to be performed within the next week or two, so it's important that you visit any XXX Group lab within two weeks to perform this test. To find out more about lab locations and hours, please contact the office directly or visit our website at XXX.org.

3. Inclusion on MyChart (patient portal) with expected completion dates



Outstanding Lab Orders (Orders in bold are overdue or due now and should be done as soon as possible)

<u>Test</u>	<u>Expected Date</u>	<u>Ordering Provider</u>
LIPID PANEL WITH REFLEX TO DIRECT LDL (Fast for 12 hours prior)	1/21/2013	Lawrence Garber, MD
FECAL GLOBIN IMMUNOCHEMICAL TEST (FALLON)	1/21/2013	Lawrence Garber, MD
VITAMIN D, 25-HYDROXY, LC/MS/MS	1/21/2013	Lawrence Garber, MD
HEPATIC FUNCTION PANEL	1/21/2013	Lawrence Garber, MD
GGT	1/21/2013	Lawrence Garber, MD
PROSTATE SPECIFIC ANTIGEN (PSA) TOTAL, SERUM	1/21/2013	Lawrence Garber, MD
BASIC METABOLIC PANEL WITH (GFR) (Fast for 6 hours prior)	1/21/2013	Lawrence Garber, MD
CBC (H/H, RBC, INDICES, WBC, PLT)	1/21/2013	Lawrence Garber, MD
LACTATE DEHYDROGENASE (LDH), SERUM	1/21/2013	Lawrence Garber, MD
URINALYSIS, COMPLETE INCLUDES DIPSTICK AND MICROSCOPIC	1/21/2013	Lawrence Garber, MD

4. Letters to patients who did not complete ordered laboratory tests within 3 weeks of expected completion date

Dear <PATIENT NAME>

{ORDERING PROVIDER First Name Last Name, Title} has ordered the following lab tests: {LAB/XRAY TESTS: 17874}. The results of this testing will help us monitor you more closely. You may have these tests performed at any of the XXX Group labs, anytime during the hours of normal operation. A specific appointment day or time is no longer required. Please bring this letter with you to the lab.

If you have recently been to the laboratory and had these studies performed, please disregard this letter.

5. Alerts to prescribers and clinic staff about patients with overdue laboratory tests

This was implemented but encountered a major problem with unintended consequences: a large bolus of additional work for clinic staff. Therefore, this intervention was canceled soon after implementation. It was replaced with the following:

Best practice alerts during office visits

This patient is due or overdue for a Basic and already has the test ordered. PLEASE REMIND THEM TO GO TO THE LAB

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Evaluation

During a 4-year period from January 2009 through October 2012, we tracked monthly laboratory test orders and completion for patients taking medications that include guideline recommendations for laboratory monitoring. Medication orders and renewals, laboratory test orders, instantiation of orders, and laboratory results were tracked using data from the medical

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group's electronic medical record. In order to control for changes in patient and provider characteristics through the time period, we also collected patient and prescriber demographic information, ambulatory office visits, diagnoses, and other utilization.

Because implementations of the components of the intervention were necessarily staggered over the project's time period, we used interrupted time series analyses to assess the impacts. We focused on two outcomes: ordering of laboratory monitoring tests within the recommended time and completion of ordered tests within 1 week of the future projected completion date included in the laboratory order. We developed multivariable models to control for important patient, prescriber and medication categories. The presence of autocorrelation was tested for each model and adjustments made to reduce its impact.

Unexpected consequences

The clinicians from the medical group who participated in the study used informal techniques to identify unexpected consequences. This included participating in clinic meetings and discussions with the group's leadership and quality management group. Through these means, we learned of the reactions to the alerts forwarded to clinic staff about patients with overdue laboratory tests. We canceled this intervention immediately and developed a replacement.

Costs

Using a study-specific tracking form, each participating investigator and staff member noted the hours spent on this project on a weekly basis and indicated the components that were specific to the development, installation, and support of the intervention components as opposed to the research effort itself. The project coordinator collected the tracking information weekly for entry into a central project time tracking database. To summarize the costs associated with development and implementation of the intervention, we applied hourly rates to the counts of personnel time, based on US Bureau of Labor Statistics summary estimates for various occupations and experience levels.¹⁰

Limitations

This study was set within one multispecialty group practice with high levels of use of HIT interventions. Generalizability is limited, although there has been a recent increase in EMR adoption among similar group practices. Because the interventions were undertaken within a functioning healthcare system, delays and obstacles were met. For example, one problem arose when an upgrade to the EMR blocked telephone reminders and lowered the rate of lab no-show letters for several months while the informatics team searched for a workaround. Implementation of the planned interventions was fully accomplished, but many interventions were introduced later than projected due to competing demands for the time of critical members of the informatics team. Therefore, there has been insufficient time to analyze the impact of two interventions: inclusion of information about ordered labs on summary sheets given to patients after office visits and inclusion of reminders of outstanding lab orders on the patient portal.

RESULTS

There were many components within this study. The results of each component are presented individually.

Component A. Patient interviews

Of the 23 patients interviewed, the mean age was 63 years; 73.9% were women; 100% were White; and 78% were prescribed a cardiovascular medication. Patient memory played the largest role in contributing to noncompletion. Of the sixteen patients who did not complete an ordered test, seven patients reported that they did not remember their lab test

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order, while four others were unaware that they did not complete a lab test order. Patient knowledge and beliefs did not appear to affect noncompletion. Most patients (17: 12 no-show, five show) were able to explain the reason for their lab test. The majority (18: 15 no-show, three show) expressed understanding of the connection between the test and their medication. None reported that they missed a lab test due to not understanding the reason for the test. Most patients (18: 12 no-show, six show) received an explanation from their provider about the reason for the lab test and expressed satisfaction with that explanation (16: 10 no-show, six show). No patient attributed a missed lab test to not receiving an explanation from his/her provider. Based on these findings, we decided to forego the development of educational materials for patients about laboratory monitoring and focused on multiple approaches for reminding them of upcoming due dates.

Component B. Baseline assessment of laboratory monitoring of high-risk medications

Many of the factors significantly associated with ordering of laboratory monitoring are related to prescriber familiarity with the patient and the drug: there was a dose-response relationship between the number of office visits for a patient and test ordering, an increased rate of ordering for patients taking multiple study drugs, higher ordering rates for chronic users of a drug, and higher ordering for drugs that the provider frequently prescribed. Other important factors that increased ordering were drugs with black box warnings from the FDA and drugs that required only annual monitoring. Prescriber age was inversely related to ordering, with only 30% of those age 60 and older ordering monitoring tests. Specialists were more likely than primary care physicians to order tests.

Analysis of patient no-shows for ordered laboratory monitoring tests also found relationships between test completion and aspects of familiarity. Chronic users of a drug were less likely to skip a test, as were those taking more than one study drug. Patients with more frequent visits to the ordering provider were also less likely to skip a test. Patient age was inversely related to noncompletion of tests, with younger patients more likely to skip. Findings from these analyses have been accepted for publication.¹¹

Component C. Assessment of impact of components of the multipronged intervention

Medications requiring laboratory monitoring were used by approximately 30,000 patients per year during the 4 years of implementation. Demographics are provided in Table 1. More than 275 providers prescribed the study drugs during the project. Demographic information was available on the majority of the prescribers (Table 2).

Table 1. Characteristics of patients age 21 and older who were taking the high-risk/study drugs from 2009 through 2012

Age as of January 1 of the year	2009	2010	2011	2012*
<40	2052 (6.4%)	2435 (7.7%)	1932 (6.2%)	1655 (5.5%)
40-49	3428 (10.7%)	3930 (12.4%)	3268 (10.5%)	3047 (10.2%)
50-59	5615 (17.6%)	5934 (18.7%)	5691 (18.4%)	5635 (18.9%)
60-69	6713 (21.0%)	6927 (21.9%)	6594 (21.3%)	6408 (21.5%)
70-79	7845 (24.6%)	7629 (24.1%)	7213 (23.3%)	6936 (23.2%)
80+	6240 (19.6%)	4808 (15.2%)	6293 (20.3%)	6160 (20.6%)

Age as of January 1 of the year	2009	2010	2011	2012*
Gender				
Female	17,957 (56.3%)	17,789 (56.2%)	17,401 (56.1%)	16,730 (56.1%)
Male	13,936 (43.7%)	13,874 (43.8%)	13,590 (43.9%)	13,111 (43.9%)
Race				
Black/African American	525 (1.3%)	581 (1.8%)	640 (2.1%)	645 (2.2%)
Asian	306 (1.0%)	335 (1.1%)	367 (1.2%)	360 (1.2%)
American Indian /Alaskan	407 (1.3%)	432 (1.4%)	459 (1.5%)	471 (1.6%)
Pacific Islander	16 (<1%)	15 (<1%)	20 (<1%)	20 (<1%)
White	23,851 (74.8%)	24,893 (78.6%)	25,742 (83.1%)	24,877 (83.4%)
Other	46 (<1%)	48 (<1%)	60 (<1%)	67 (<1%)
Unknown	6742 (21.1%)	5359 (16.9%)	3703 (11.9%)	3401 (11.4%)
Ethnicity				
Hispanic	661 (2.1%)	727 (2.3%)	817 (2.6%)	8106 (2.7%)
Non-Hispanic	21,337 (66.9%)	22,333 (70.5%)	23,191 (74.8%)	22,449 (75.2%)
Unknown	9895 (31.03%)	8603 (27.2%)	69,839 (22.5%)	6582 (22.1%)

*Partial year, 10.5 months of data available

Table 2. Characteristics of providers who prescribed high-risk/study drugs in 2009 through 2012

	2009	2010	2011	2012
Age				
<40	38 (17%)	51 (20%)	46 (18%)	40 (15%)
40-49	54 (24%)	55 (22%)	48 (18%)	43 (16%)
50-59	62 (27%)	62 (25%)	64 (24%)	60 (22%)
60+	16 (7%)	13 (5%)	31 (12%)	38 (14%)
Not available	60 (26%)	69 (28%)	73 (28%)	87 (32%)
Gender				
Female	101 (44%)	116 (46%)	128 (49%)	132 (49%)
Male	121 (53%)	130 (52%)	131 (50%)	132 (49%)
Not available	8 (3%)	4 (2%)	3 (1%)	4 (2%)
Physician	145 (63%)	155 (62%)	177 (68%)	181 (68%)
NP/PA	39 (15%)	48 (19%)	55 (21%)	65 (24%)
Other	45 (20%)	46 (19%)	30 (12%)	21 (8%)

1. Analysis of the impact of adding automated alerts at the time of medication renewal
 These alerts were completed and implemented for all the clinic sites at the end of 2011. We analyzed possible changes in the percent of recommended tests that were ordered using an interrupted time series model, including monthly rates of recommended test ordering from January 2010 through June 2012 (data on lab ordering is still incomplete for the subsequent months). The Durbin-Watson statistics indicated no significant level of autocorrelation.

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The estimated effect of the intervention on rates of ordering with control for provider age and type was an increase of 6% (95% confidence interval [CI] 0.1%, 12.3%).

2. Analysis of the impact of adding SmartSet directions for ordering laboratory tests for a subset of study drugs to the EMR

These alerts were gradually added clinic site by clinic site and were completed at the end of 2010. We analyzed possible changes in the percent of recommended tests that were ordered using an interrupted time series model, including monthly rates of recommended test ordering from August 2009 through June 2012. The Durbin-Watson statistics indicated autocorrelation that was successfully corrected. The autoregression procedure with control for provider age and type found a slight increase in the rate of test ordering after full implementation of 1.3%, but this was not statistically significant (95% CI -25.1%, +27.6%).

3. Analysis of the impact of implementing telephone reminders on patient completion of ordered laboratory tests

Telephone reminders were initiated in March 2010. We analyzed changes in the percent of ordered tests completed using an interrupted time series model, including monthly rates of test completion from August 2009 through June 2012, with an indicator variable for the period of time when the EMR upgrade blocked the reminders from being generated. The Durbin-Watson statistics indicated a substantial amount of autocorrelation that was corrected for 2-lag. The autoregression procedure with control for patient age and number of study drugs currently taken found a reduction in the rate of test completion of -2.5%, which was not statistically significant (95% CI -5.6%, +.05%).

4. Analysis of the impact of providing best practice alerts to providers during office visits to remind patients of upcoming lab tests

Best practice alerts were implemented as a replacement for the original automated alerts to clinic staff that had resulted in excess work for busy offices. Best practice alerts were a late decision and were not fully implemented until April 2012. Despite the short post-intervention period, we analyzed any short-term impact on the percent of ordered tests completed using an interrupted time series model that used monthly rates of test completion from August 2009 through June 2012. The Durbin-Watson statistics indicated autocorrelation that was successfully corrected. The autoregression procedure with control for patient age and number of study drugs currently taken found an increase in completion of 6.5%, which was not statistically significant (95% CI -5.7%, +18.8%).

Component D. Costs of interventions to improve laboratory monitoring of high-risk medications

Interventions to improve ordering of laboratory tests

1. Automated alerts at the time of medication renewal
160 hours of physician/informatacist @ \$90.13
total: \$14,420.80
2. SmartSet directions for ordering laboratory tests
40 hours of physician/informatacist @ \$90.13
total: \$3605.20

Interventions to improve patient completion of ordered laboratory tests

1. Inclusion of ordered labs and due dates on after visit summary sheets
with negligible amount of time to invoke a capability included in the EMR
2. Automated telephone reminders

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Development

280 hours of a computer software engineer @ \$42.30

60 hours of a physician/informaticist @ \$90.13

Set-up fee with external contractor: \$3000

total: \$20,251.80

Ongoing costs

Contractual arrangement with a monthly minimum fee; currently \$1500

3. Inclusion on MyChart (patient portal) with expected lab completion date

20 hours of physician/informaticist @ \$90.13

total: \$1802.60

4. Automated production and mailing of letters to patients who did not complete ordered laboratory tests within 3 weeks of expected completion date

Development

384 hours of a computer systems analyst @ \$39.10

6 hours of a physician/informaticist @ \$90.13

total: \$15,555.18

Ongoing costs

average per-letter costs in 2012: \$0.77

5. Best practice alerts during office visits

30 hours of physician/informaticist @ \$90.13; total: \$2703.90

Discussion

Within this project, we performed a series of analyses to better understand the factors underlying inadequate laboratory monitoring and found that inadequate laboratory monitoring of high-risk medications is the result of prescribers not ordering tests as well as patients not completing ordered tests. Various factors are associated with both aspects of the problem, and many of them are related to issues of familiarity with the drugs, the patients, and the prescribers.

We built on these findings to develop interventions directed at increasing both the ordering of lab tests by prescribers and their completion by patients. Each of the interventions increased one aspect of monitoring, but only the alerts presented to prescribers at the time of medication renewal led to a statistically significant increase in monitoring. This intervention was the most direct alternative, and it included all the study drugs. Its positive impact suggests that this approach should be extended to include new prescriptions of high-risk medications.

Despite interviews with patients that suggested forgetting as the major cause of missed laboratory tests, we were surprised to find that neither intervention aimed at reminding patients of tests produced an increase in completion. The most recent attempts to improve this were implemented too late to be analyzed within this project, but we will continue to track their impact.

The unexpected consequence of our attempt to alert clinic staff to patients with missed lab tests highlights the importance of understanding and accommodating workflow issues when adding interventions to an existing clinical system. The intervention was immediately canceled, and there were no problems identified for the remaining interventions.

Within the medical group that served as the base for this project, the 4 years of the study saw a range of developments that may have impacted our results. For example, complications in the billing system for the primary insurer that occurred during this project may have caused patients to hesitate at paying copays for tests that they perceived as less essential. Other modifications and enhancements to the EMR and institution of the patient portal may have led to alert "overkill" for providers and impeded full and timely implementation of the HIT interventions.

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Estimates of the cost of developing and implementing the interventions found extensive time required from a physician/informaticist, especially for development of the alerts to prescribers. Other interventions relied more heavily on computer system analysts and software engineers. Two of the interventions involved ongoing costs, particularly for the use of telephone reminders to patients, which were not found to be effective.

Conclusion

Increasing laboratory monitoring of high-risk medications requires attention to both test ordering and test completion. Within a medical group with informatics capabilities, there are various alternative interventions that may be implemented to increase both ordering and completion of tests. However, we found that only one intervention significantly increased monitoring: automated alerts to prescribers at the time of renewing medication prescriptions.

LIST OF PUBLICATIONS AND PRODUCTS (Bibliography of Published Works and Electronic Resources from Study)

Journal publications

Tjia J, Field TS, Garber LD, et al. Development and pilot testing of guidelines to monitor high-risk medications in the ambulatory setting. *Am J Manag Care* 2010;16(7):489-496.

Objectives: To develop guidelines to monitor high-risk medications and to assess the prevalence of laboratory testing for these medications among a multispecialty group practice.
Study Design: Safety intervention trial

Methods: We developed guidelines for the laboratory monitoring of high-risk medications as part of a patient safety intervention trial. An advisory committee of national experts and local leaders used a two-round, internet-based Delphi process to select guideline medications based on the importance of monitoring for efficacy, safety, and drug-drug interactions. Test frequency recommendations were developed by academic pharmacists based on a literature review and local interdisciplinary consensus. To estimate the potential effect of the planned intervention, we determined the prevalence of high-risk drug dispensing and laboratory testing for guideline medications between January 1, 2008, and July 31, 2008.

Results: Consensus on medications to include in the guidelines was achieved in two rounds. Final guidelines included 35 drugs or drug classes and 61 laboratory tests. The prevalence of monitoring ranged from less than 50.0% to greater than 90.0%, with infrequently prescribed drugs having a lower prevalence of recommended testing ($P<.001$ for new dispensing and $P<.01$ for chronic dispensing, nonparametric test for trend). When more than one test was recommended for a selected medication, monitoring within a medication sometimes differed by greater than 50.0%.

Conclusions: Even among drugs for which there is general consensus that laboratory monitoring is important, the prevalence of monitoring is highly variable. Furthermore, infrequently prescribed medications are at higher risk for poor monitoring.

Fischer SH, Tjia J, Field TS. Impact of health information technology interventions to improve medication laboratory monitoring for ambulatory patients: a systematic review. *J Am Med Inform Assoc* 2010;17(6):631-6.

Medication errors are a major source of morbidity and mortality. Inadequate laboratory monitoring of high-risk medications after initial prescription is a medical error that contributes to preventable adverse drug events. Health information technology (HIT)-based clinical decision support may improve patient safety by improving the laboratory monitoring of high-risk medications, but the effectiveness of such interventions is unclear. Therefore, the authors conducted a systematic review to identify studies that evaluate the independent effect of HIT interventions on improving laboratory monitoring for high-risk medications in the ambulatory setting using a Medline search from January 1, 1980, through January 1, 2009, and a manual review of relevant bibliographies. All anticoagulation monitoring studies were excluded. Eight articles met the inclusion criteria, including six randomized controlled trials and two pre-post intervention studies. Six of the studies were conducted in two large, integrated healthcare delivery systems in the USA. Overall, five of the eight studies reported statistically significant, but small, improvements in laboratory monitoring; only half of the randomized controlled trials reported statistically significant improvements. Studies that found no improvement were more likely to have used analytic strategies that addressed clustering and confounding. Whether HIT improves laboratory monitoring of certain high-risk medications for ambulatory patients remains unclear, and further research is needed to clarify this important question.

AHRQ Grant Final Progress Report

Field, Terry S.

Grant Award Number: R18HS017906

Tjia J, Fischer SH, Raebel MA, et al. Baseline and follow-up laboratory monitoring of cardiovascular medications. *Ann Pharmacother* 2011;45(9):1077-1084.

Background: Laboratory monitoring of medications is typically used to establish safety prior to drug initiation and to detect drug-related injury following initiation. It is unclear whether black box warnings (BBWs) as well as evidence- and consensus-based clinical guidelines increase the likelihood of appropriate monitoring.

Objective: To determine the proportion of patients newly initiated on selected cardiovascular medications with baseline assessment and follow-up laboratory monitoring and compare the prevalence of laboratory testing for drugs with and without BBWs and guidelines.

Methods: This cross-sectional study included patients aged 18 years or older from a large multispecialty group practice who were prescribed a cardiovascular medication (angiotensin converting enzyme inhibitors, angiotensin II receptor blockers, amiodarone, digoxin, lipid-lowering agents, diuretics, and potassium supplements) between January 1 and July 31, 2008. The primary outcome measure was laboratory test ordering for baseline assessment and follow-up monitoring of newly initiated cardiovascular medications.

Results: The number of new users of each study drug ranged from 49 to 1757 during the study period. Baseline laboratory test ordering across study drugs ranged from 37.4% to 94.8%, and follow-up laboratory test ordering ranged from 20.0% to 77.2%. Laboratory tests for drugs with baseline laboratory assessment recommendations in BBWs were more commonly ordered than for drugs without BBWs (86.4% vs 78.0%, $P < 0.001$). Drugs with follow-up monitoring recommendations in clinical guidelines had a lower prevalence of monitoring (33.1% vs 50.7%, $P < 0.001$).

Conclusions: Baseline assessment of cardiovascular medication monitoring is variable. Quality measurement of adherence to BBW recommendations may improve monitoring.

Tjia J, Field TS, Fischer SH, et al. Quality measurement of medication monitoring in the "meaningful use" era. *Am J Manag Care* 2011;17(9):633-637.

Objectives: While the 2011 implementation of "meaningful use" legislation for certified electronic health records (EHRs) promises to change quality reporting by overcoming data capture issues affecting quality measurement, the magnitude of this effect is unclear. We compared the measured quality of laboratory monitoring of Healthcare Effectiveness Data and Information Set (HEDIS) medications based on specifications that (1) include and exclude patients hospitalized in the measurement year and (2) use physician test orders and patient test completion.

Study design: Cross-sectional study

Methods: Among patients 18 years and older in a large, multispecialty group practice utilizing a fully implemented EHR between January 1, 2008, and July 31, 2008, we measured the prevalence of ordering and completion of laboratory tests monitoring HEDIS medications (cardiovascular drugs [angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, digoxin, and diuretics] and anticonvulsants [carbamazepine, phenobarbital, phenytoin, and valproic acid]).

Results: Measures excluding hospitalized patients were not statistically significantly different from measures including hospitalized patients, except for digoxin, but this difference was not clinically significant. The prevalence of appropriate monitoring based on test orders typically captured in the EHR was statistically significantly higher than the prevalence based on claims-based test completions for cardiovascular drugs.

Conclusions: HEDIS quality metrics based on data typically collected from claims underestimated quality of medication monitoring compared to EHR data. The HEDIS optional specification excluding hospitalized patients from the monitoring measure does not have a significant impact on reported quality. Integration of EHR data into quality measurement may significantly change some organizations' reported quality of care.

AHRQ Grant Final Progress Report

Field, Terry S.

Grant Award Number: R18HS017906

Fischer SH, Field TS, Gagne SJ, et al. Patient completion of laboratory tests to monitor medication therapy: a mixed-methods study. *J Gen Intern Med* epub ahead of print; PMID:23229907.

Background: Little is known about the contribution of patient behavior to incomplete laboratory monitoring, and the reasons for patient noncompletion of ordered laboratory tests remain unclear.

Objective: To describe factors, including patient-reported reasons, associated with noncompletion of ordered laboratory tests

Design: Mixed-methods study including a quantitative assessment of the frequency of patient completion of ordered monitoring tests combined with qualitative, semi-structured, patient interviews

Participants: Quantitative assessment included patients 18 years or older from a large multispecialty group practice prescribed a medication requiring monitoring. Qualitative interviews included a subset of show and no-show patients prescribed a cardiovascular, anticonvulsant, or thyroid replacement medication.

Main Measures: Proportion of recommended monitoring tests for each medication not completed, factors associated with patient noncompletion, and patient-reported reasons for noncompletion

Key Results: Of 27,802 patients who were prescribed one of 34 medications, patient noncompletion of ordered tests varied (range 0% to 24%) by drug-test pair. Factors associated with higher odds of test noncompletion included younger patient age (<40 years vs ≥80 years, adjusted odds ratio [AOR] 1.52, 95% confidence interval [95% CI] 1.27-1.83), lower medication burden (one medication vs more than one drug, AOR for noncompletion 1.26, 95% CI 1.15-1.37), and lower visit frequency (0-5 visits/year vs ≥19 visits/year, AOR 1.41, 95% CI 1.25-1.59). Drug-test pairs with black box warning status were associated with greater odds of noncompletion compared with drugs without a black box warning or other guideline for testing (AOR 1.91, 95% CI 1.66-2.19). Qualitative interviews, with 16 no-show and seven show patients, identified forgetting as the main cause of noncompletion of ordered tests.

Conclusions: Patient noncompletion contributed to missed opportunities to monitor medications and was associated with younger patient age and lower medication burden and black box warning status. Interventions to improve laboratory monitoring should target patients as well as physicians.

Conference presentations

Tjia J, Field TS, Garber L, et al. Development and pilot testing of guidelines to monitor high-risk medications in the ambulatory setting and post-hospital discharge. AHRQ Annual Conference. 2009 Sep 13-16; Bethesda, MD.

Tjia J, Field T, Garber L, et al. Development and pilot testing of guidelines to monitor high-risk medications in the ambulatory setting. 16th Annual HMO Research Network Conference; 2010 Mar 21-24; Austin, TX.

Fischer SH, Tjia J, Field TS, et al. Understanding laboratory monitoring of high-risk cardiovascular drugs: identifying the relative contribution of physician and patient adherence to monitoring measurements. AHRQ Annual Health IT Grantee and Contractor Meeting. 2010 Jun 2-4; Washington, DC.

Tjia J, Field T, Raebel M, et al. PS1-40: Laboratory Monitoring of HEDIS Medications in the Ambulatory Setting: The Relative Contribution of Physician and Patient Behavior to Undermonitoring. 17th Annual HMO Research Network Conference; 2011 Mar 23-25; Boston, MA. *Clin Med Res*. Nov 2011;9(3-4):178-179.

AHRQ Grant Final Progress Report
Field, Terry S.
Grant Award Number: R18HS017906

Fischer SH, Gagne SJ, Preusse P, et al. Why patients fail to complete laboratory monitoring requests. 17th Annual HMO Research Network Conference; 2011 Mar 23-25; Boston, MA.

Tjia J, Field TS, Fischer SH, et al. Quality measurement issues in the era of meaningful use: lessons from the laboratory monitoring of high-risk medications. University of Massachusetts Center for Clinical and Translational Science Annual Research Retreat. 2011 May 20; Shrewsbury, MA.

Fischer SH, Field TS, Gagne SJ, et al. Patient adherence to laboratory tests to monitor medication therapy: a mixed-methods study. University of Massachusetts Center for Clinical and Translational Science Annual Research Retreat. 2012 May 22; Shrewsbury, MA.

Fischer SH, Field TS, Peterson D, et al. Factors associated with ordering laboratory monitoring of high-risk medications. University of Massachusetts Center for Clinical and Translational Science Annual Research Retreat. 2012 May 22; Shrewsbury, MA.

Webinar presentations

Gurwitz JH, Field TS. Potential of health IT for prescribing and monitoring medication for older adults. National Web-Based Teleconference on Utilizing Health IT to Improve Medication Management for the Care of Elderly Patients. 2011 Aug 18. Agency for Healthcare Research and Quality. 2011 Nov.

http://healthit.ahrq.gov/portal/server.pt/document/955352/accessible%2Baugust%2Bnational%2Bweb-based%2Bteleconference_pdf

Garber L. Achieving a higher level of patient safety with electronic health records and health information exchanges. National Patient Safety Foundation Webinar. 2010 Jul 28. National Patient Safety Foundation. 2010. http://www.npsf.org/wp-content/uploads/2011/10/PLS_1007_LG.pdf

REFERENCES

1. Gurwitz JH, Field TS, Harrold LR, et al. Incidence and preventability of adverse drug events among older persons in the ambulatory setting. *JAMA* 2003 Mar 5;289(9):1107-1116.
2. Raebel MA, McClure DL, Simon SR, et al. Frequency of serum creatinine monitoring during allopurinol therapy in ambulatory patients. *Ann Pharmacother* 2006 Mar;40(3):386-391.
3. Raebel MA, Carroll NM, Simon SR, et al. Liver and thyroid monitoring in ambulatory patients prescribed amiodarone in 10 HMOs. *J Manag Care Pharm* 2006 Oct;12(8):656-664.
4. Raebel MA, McClure DL, Chan KA, et al. Laboratory evaluation of potassium and creatinine among ambulatory patients prescribed spironolactone: are we monitoring for hyperkalemia? *Ann Pharmacother* 2007 Feb;41(2):193-200.
5. Raebel MA, McClure DL, Simon SR, et al. Laboratory monitoring of potassium and creatinine in ambulatory patients receiving angiotensin converting enzyme inhibitors and angiotensin receptor blockers. *Pharmacoepidemiol Drug Saf* 2007 Jan;16(1):55-64.
6. Hurley JS, Roberts M, Solberg LI, et al. Laboratory safety monitoring of chronic medications in ambulatory care settings. *J Gen Intern Med* 2005 Apr;20(4):331-333.
7. Overhage JM, Tierney WM, Zhou X-H, et al. A randomized trial of "corollary orders" to prevent errors of omission. *J Am Med Inform Assoc* 1997 Sep 1;4(5):364-375.
8. Tjia J, Field TS, Garber LD, et al. Development and pilot testing of guidelines to monitor high-risk medications in the ambulatory setting. *Am J Manag Care* 2010;16:489-496.
9. Glaser B, Strauss A. *Grounded Theory: The Discovery of Grounded Theory*. New York: de Gruyter; 1967.
10. National Compensation Survey: *Occupational earnings in the United States, 2009*. Occupational earnings tables: United States, December 2008-January 2010. Washington, DC: US Department of Labor. June 2010. <http://www.bls.gov/ncs/ncswage2009.pdf>. Accessed November 15, 2010.
11. Fischer SH, Field TS, Gagne SJ, et al. Patient completion of laboratory tests to monitor medication therapy: a mixed-methods study. *J Gen Intern Med* epub ahead of print; PMID:23229907.