Project Title: Proactive Risk Reduction in Medication Prescribing in the Ambulatory Setting

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Structured abstract

Purpose: To use probabilistic risk assessment to characterize systemic and behavioral elements that increase the risk of serious errors in prescribing and monitoring medications in the ambulatory care setting and identify potentially high-yield and likely-to-be-successful interventions for lowering rates of preventable adverse drug events.

Scope: There are currently no demonstrably effective solutions to the problem of errors in prescribing and monitoring medications in ambulatory clinics. Our previous study identified seven major proximal errors in the medication handling process that cause serious adverse events.

Methods: Based on techniques from sociotechnical probabilistic risk assessment and fault tree analysis, two teams of clinicians and staff from a multispecialty group practice brainstormed to create fault trees describing the system failures leading to the seven errors. Qualitative and quantitative cut-set analyses were used to identify points for interventions and assess the extent to which these interventions could lower the rate of these errors.

Results: It is not difficult to engage clinicians in a probabilistic risk assessment endeavor. The PRA process is quickly learned and is interesting for the participants. Probabilistic risk assessment can reveal important issues in the clinical system. The most critical issues identified were lack of redundancy and communication flow problems.

Key words: probabilistic risk assessment, adverse drug events, ambulatory setting

Purpose

In our previous study of preventable adverse drug events among 30,000 older adults treated in the ambulatory setting by a multispecialty group practice over a 1-year period,[1] we found a rate of adverse drug events of 50.1 per 1000 person-years, with a rate of 13.8 preventable adverse drug events per 1000 person-years. Of the serious, life-threatening, and fatal ADEs, 244, or 42%, were judged to be preventable. During that study, we also identified errors that were the proximal causes of these serious, life-threatening, and fatal preventable events: drug interactions, medications conflicting with recent laboratory values indicating high risk, medications for which patients had a history of allergies or prior reactions, lack of accompanying prophylaxis for known side effects, excessive dosing, inadequate laboratory monitoring, failure to act on monitoring (e.g., high INR levels in patients on warfarin), and medications that were not appropriate for a patient's medical conditions.

The aims of this project, directed at better understanding these findings, were to use probabilistic risk assessment to:

a. characterize systemic and behavioral elements that increase the risk of serious errors in prescribing and monitoring medications for older adults in the ambulatory care setting and
b. identify potentially high-yield and likely-to-be-successful interventions for lowering rates of preventable adverse drug events in that setting.

Additional aims were to estimate the likelihood that various interventions would be successful in reducing errors at that step, select interventions for implementation, and develop action plans for implementing identified interventions.

Scope

Background

Drugs are widely prescribed in the ambulatory setting. The most recent Slone survey of prescription medication use in 2005 found that 50% of adults over the age of 18 were taking at least one prescribed medication, with 10% taking five or more.[2] There was a strong age effect, with 80% of those age 65 and older reporting use of prescription medications and 30% of this age group taking five or more. Since the 1998-99 survey, the percent of adults taking five or more medications has increased from 7.3% to 10%, and the percent taking 10 or more has increased from 0.5% to 1%.

Adverse drug events (ADEs), especially those that may be preventable, are among the most serious concerns about medication use in the ambulatory setting. In our own research, we have found rates of 50 per 1000 person-years, of which 28% resulted from errors in the medication-handling process. Among the ADEs identified, the more serious events were more often preventable In this setting, errors in the prescribing and monitoring stages of medication management predominate.

A recent systematic review and meta-analysis of interventions to reduce ADEs identified 38 studies including interventions using pharmacists and other healthcare providers.[3] Although the pharmacist-based interventions appeared to be effective in the overall analysis, a subanalysis limiting studies to those using a randomized trial design found no benefit. Pooled analysis of the non-pharmacist-led interventions found no effect. A recent, well-designed randomized trial of a pharmacist intervention directed at lowering the number of medications prescribed for elderly patients found no effect.[4]

The interventions attempted in the ambulatory setting have usually been directed at changing physician behavior. Because the errors associated with ADEs in this setting usually occur

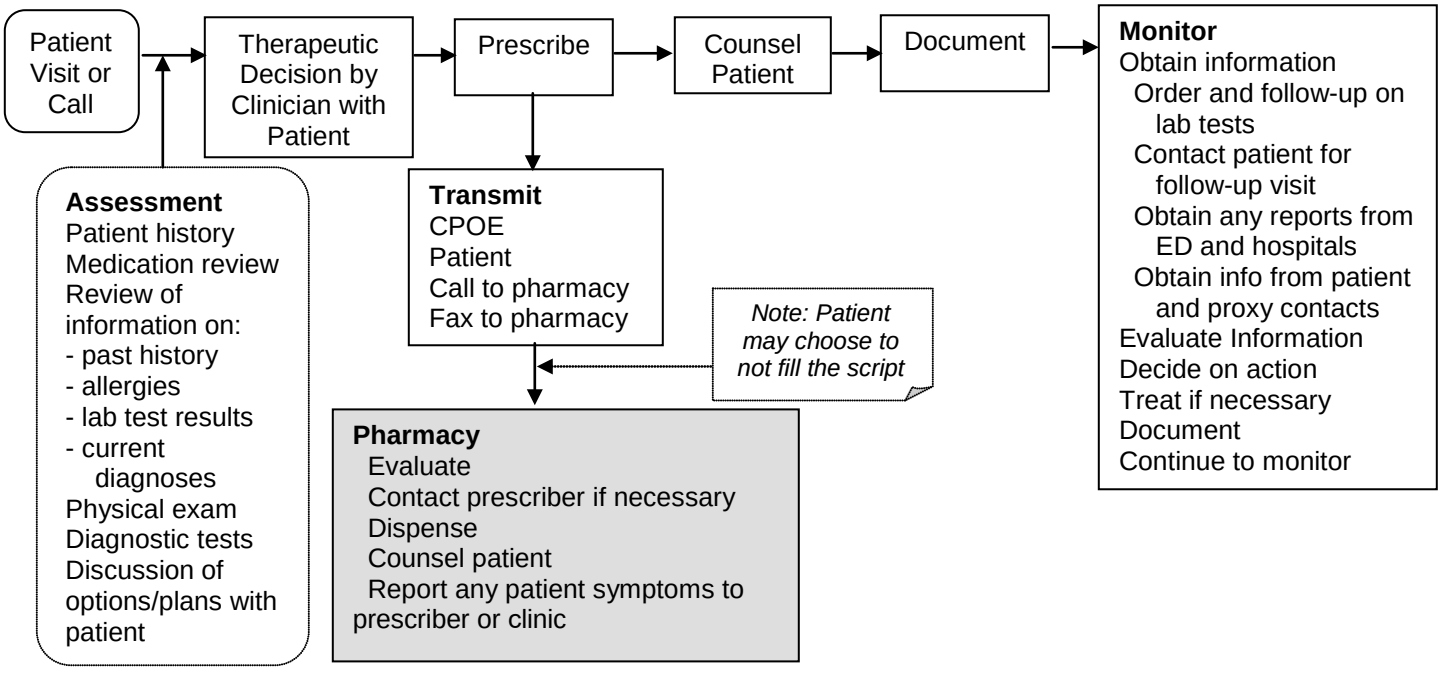
during prescribing and monitoring medications, as suggested by our own research, this idea is logical. However, changing physician behavior is a difficult process. Interventions that have been tested for modifying a variety of physician behaviors have rarely been effective. An overview of systematic reviews of interventions found that passive approaches were generally ineffective and that no interventions were effective under all circumstances.[5]

In summary, there are currently no demonstrably effective solutions to the problem of errors in prescribing and monitoring medications in ambulatory clinics. However, there are potential opportunities to intervene by changing other aspects of the medication handling system that may underlie these errors or by mistake-proofing the process by blocking inappropriate prescribing from affecting patients. A number of risk assessment techniques developed and widely used in industry have been adapted for use in healthcare settings that may support identification of alternative interventions. Among these techniques, several are proactive and offer the opportunity to analyze the underlying failures leading to the proximal errors responsible for serious ADEs and discern interventions with the potential to improve patient safety.

Context of the project

The project was designed as a risk assessment directed at selecting interventions to lessen the rate of serious adverse drug events occurring in the ambulatory setting of care. It was conducted collaboratively with colleagues from a closely affiliated organization providing ambulatory healthcare, the Fallon Clinic of Central Massachusetts. The Fallon Clinic is the healthcare provider organization participating in this study. Fallon Clinic is a 240-provider multispecialty group practice begun in 1929 that currently includes 30 ambulatory clinic sites and provides medical care for approximately 131,000 patients, of whom 25,000 are aged 65 or older. The Clinic is located in Worcester, Massachusetts, and draws its patients from the working and middle class communities in central Massachusetts.

Figure 1. Medication handling process at Fallon Clinic

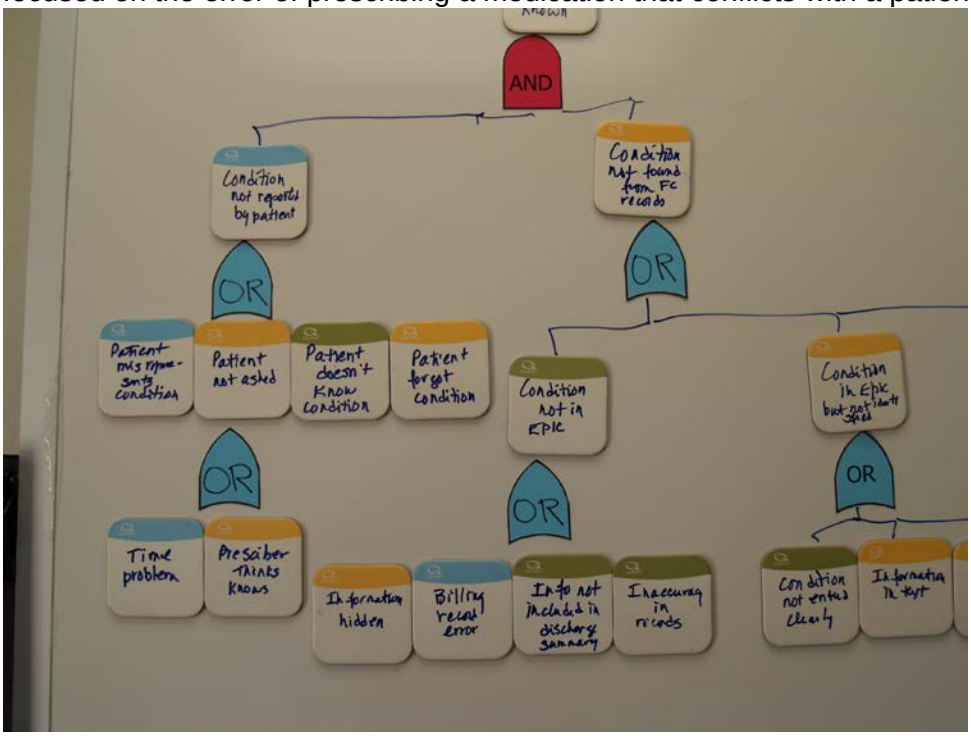


Methods

Process

Risk assessment was based on techniques from sociotechnical probabilistic risk assessment and fault tree analysis and used brainstorming by teams of clinicians representing all levels of care. We created two interdisciplinary risk modeling teams of six members, including at least one primary care and one specialist physician and/or a nurse practitioner, a nurse manager, a clerical medical assistant, and a pharmacist. Each team was led by a clinician with previous team-leading experience: team 1 by Dr. Lawrence Garber, who is a co-investigator on the project, and team 2 by Karen Fleming, a nurse practitioner. Teams were trained jointly but held their working meetings individually.

Each brainstorming session was designed to construct a fault tree for one specific proximal error in the medication prescribing and monitoring process at the clinic. We used large white boards and write-on magnets to construct the tree. Here is an example from the session that focused on the error of prescribing a medication that conflicts with a patient's medical condition.



Fault tree components were documented with digital photography for later input into probabilistic risk assessment software, described below.

Team 1 held sessions on prescribing a drug for which the patient has a known allergy, prescribing a drug that interacts with a drug the patient is also taking, inadequate monitoring of high-risk medications, and failure to act on monitoring. Team 2 held sessions on failure to provide prophylaxis for known side effects, prescribing a drug that conflicts with a patient's medical conditions, and prescribing an excess dose of a drug.

We selected the Saphire software package for constructing and analyzing the fault trees. A research assistant input the information and produced a fault tree for review by the investigator team immediately following each brainstorming session so that any issues or corrections could be brought to that team during their next session.

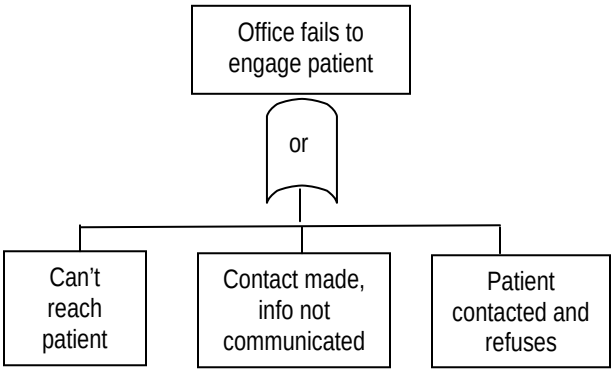
In order to run cut-set analyses and identify potential points for interventions, we needed to assign frequencies to each of the events on the fault trees. Very few of the events identified by the teams were appropriate for direct measurement. For example, we needed frequencies for events such as “lab results are faxed to the wrong office,” “clerk fails to enter lab results into the electronic medical record,” and “prescriber believes s/he knows all of the patient’s conditions so does not check before prescribing a medication.” Therefore, we held additional sessions with the risk modeling teams to use their knowledge and experience to estimate the frequencies of these events. This was a much more difficult process than would be needed to estimate the frequencies of mechanical problems. We considered several approaches for accomplishing this and talked them through with team members. Eventually, we designed an approach that enabled us to collect this information. This approach also had some surprising and very useful side effects. For each fault tree, we reviewed the literature to estimate how often the top, proximal error is likely to occur:

Proximal Error	% of Drug Orders with this Error
prescribing a drug for which the patient has a known allergy	3
prescribing a drug that interacts with a drug the patient is also taking	7
inadequate monitoring of high-risk medications	36
failure to provide prophylaxis for known side effects	1
prescribing a drug that conflicts with a patient’s medical conditions	3
prescribing an excess dose of a drug	1

There was no evidence in the literature to allow estimates of the error “failure to act on monitoring.” We worked with the clinicians on our investigator team to estimate this, using clinic data and the results from previous studies by the HMO Center for Education and Research on Therapeutics.[6-12] We estimated that 0.5% of drug orders require monitoring, receive monitoring, demonstrate a potential problem, and are ignored.

The teams worked their way down through each fault tree, deciding how to apportion frequencies across options for each level of the tree. Thus, for the fault tree for prescribing a drug that interacts with another drug the patient is taking, the first branching was an OR gate with the following options: physician is ordering the drug using the e-prescribing system and neither the physician nor the computer system recognizes the interaction, **or** the physician is ordering the drug without the computer and does not know realize the interaction, **or** the physician is ordering the drug using the computer and is notified of the interaction but ignores it. Using our approach, the team had to decide how often each of these are responsible for interacting drug orders. They estimated that 20% of interacting drug orders are caused by the physician and computer system not recognizing the interaction, 20% are caused by the physician prescribing without the computer and not recognizing the interaction, and 60% are caused by the physician receiving a notification from the computer about the interaction and ignoring it.

Another example, focused on issues within the office, is from the fault tree for inadequate lab monitoring:



For this component of the fault tree, the team estimated that 80% of the office failures to engage the patient are caused by their inability to reach the patient, 5% of the these failures are due to the information not being correctly communicated to the patient, and 15% are due to patient refusals.

Forcing the team to agree on these apportionments led to very interesting exchanges. Specialists and primary care physicians often had very different perspectives, as did nurses and clerical medical assistants. Forcing them to make these choices brought these differences to the fore and led to substantial amounts of cross-specialty learning for all participants. These sessions were the most interesting of the project.

For each fault tree, the investigator team calculated the overall percent time that each event occurred by working down through the tree, multiplying each estimated frequency by the frequency of the event just above it.

Patient Interviews

We conducted interviews with 10 patient volunteers who were suggested by members of the teams. The interviews were conducted after completion of the construction of the fault trees and were directed at seeking the patient perspective on several major areas, including the way in which their allergies are handled by the clinic staff, how their physicians and staff communicate with them about their medications, communications about new prescriptions, issues in the linkage between the clinic and the pharmacies that they use, and interactions with the laboratory.

Analysis

Qualitative analyses consisted of reviews of the basic structure of the fault trees and review of the patient interviews. We specifically reviewed the patterns of AND and OR gates to assess problems related to lack of redundancy, identified areas with very long strings of OR gates reinforcing the need for quantitative analysis, sought specific errors that by-passed internal safety oriented systems, and identified components that recurred across trees. Quantitative analyses used Saphire software for cut-set analyses. We entered the calculated frequencies for each event on the trees and ran a series of analyses. We began by reviewing the overall cut-set results based on the constructed fault trees. We followed that by estimating the potential reductions in the frequencies of critical events that could be accomplished through proposed interventions and re-ran the trees.

Results

Qualitative Findings from the Fault Trees

One aspect of the fault trees stood out immediately: the lack of redundancy in the clinical system. For many proximal errors, a long string of events would lead to the error occurring with no safety checks and no points in the clinic's system at which the path to the proximal error would be blocked. This was particularly important for the inadequate laboratory monitoring error. We had previously found this error to be responsible for 41% of the preventable serious adverse drug events occurring in the ambulatory setting – the largest percent of any of the errors identified. In a series of studies by sites in the HMO Center for Education and Research on Therapeutics including Fallon Clinic, laboratory monitoring was missed an average of 40% of the time,[6-12] making this by far the most frequent medication handling error. Thus, the lack of redundancy found in the fault tree for this error was a major finding. As we were continuing the project, members of the clinic staff began to take spontaneous action on several

of the frequent events on this fault tree by establishing several working groups of clinic staff to tackle these system failures: 1) a Patient Contact Update working group and 2) a Lab No-show Committee. The Patient Contact Update Working Group has initiated a process that calls for receptionists in all Fallon Clinic offices to update patients' addresses and telephone numbers during each visit. This process is fully implemented. The Lab No-show Committee designed and implemented a system to clean the existing data about laboratory "no shows" (patients who are overdue for laboratory tests), pilot tested the system at two clinic sites, and now has expanded cleaning of the "no show" backlog to the entire clinic.

Qualitative Findings from the Patient Interviews

The patient responses confirmed areas that had been identified in the fault trees. However, several key issues emerged. First, patients had total faith that their physicians were totally committed to them and knew everything necessary about them. Any problems that they encountered were ascribed to the insurer or the system. Second, the lack of a reminder system for laboratory appointments frequently leads to missed appointments. Because the patients were specifically referred by clinic physicians, we believe the issues raised are an underestimate. We will expand this patient group in the follow-up implementation project that we are now undertaking.

Quantitative Findings

For each proximal errors, we began with the probability of the event with no interventions and calculated the potential reduction in this probability through system changes that reduce the probability of sets of events on the tree. The major results are:

Fault Tree: Known Allergy—Probability .0309

1. Improvement in Patient Issues
    a. Patient Knows Allergy But Not Drug Class (probability reduced by 50%)
    b. Patient Didn't Have It Written Down (probability reduced by 50%)
    c. Patient Forgets (probability reduced by 50%)
    d. Patient Doesn't Recognize Importance of Allergy (probability reduced by 50%)
        - **Probability decreases from .0309 to .01321 (a reduction of .0177** (57.25%)**)**
2. Improve Intake/Contacts During Visits
    a. Not Part of Standard Workflow (probability reduced by 75%)
    b. Lack of Training (probability reduced by 75%)
        - **Probability decreases from .0309 to .02381 (a reduction of .0071** (22.94%)**)**
3. Combining Patient Issues and Improve Intake/Contacts During Visits
        - **Probability decreases from .0309 to .01017 (a reduction of .0208** (67.08%)**)**

Fault Tree: Drug Interactions—Probability .07141

1. Improved communications with the Veterans' Administration health system (probability reduced by 100%)
        - **Probability decreases from .07141 to .0683 (a reduction of .00311** (4.3%)**)**
2. Improvement in Patient Issues
    a. Patient Does Not Have List of Medications (probability reduced by 100%)
    b. Patient Forgets Medications Taking (probability reduced by 100%)

- **Probability decreases from .07141 to .05102 (a reduction of .02039** (28.43%)**)**

3. Reducing frequency of MD not noticing drugs in the medical record through improvements to the EMR (probability reduced by 75%)
    - **Probability decreases from .07141 to .03787 (a reduction of .03354** (46.77%)**)**
4. Improve the CPOE system's inclusion of drug interactions (probability reduced by 100%)
    - **Probability decreases from .07141 to .06851 (a reduction of .0029** (4.04%)**)**
5. Train office staff to obtain more information
    a. Reduce office being too busy (probability reduced by 100%)
    b. Improve training (probability of lack of training reduced by 50%)
    c. Modify office priorities (probability of other priorities reduced by 50%)
    - **Probability decreases from .07141 to .05779 (a reduction of .01362** (19.00%)**)**

Fault Tree: Inadequate Monitoring—Probability .3643

1. Improvement in Patient Issues
    a. Patient is Contacted and Refuses (probability reduced by 25%)
    b. Patient Fails to Follow Instructions (probability reduced by 50%)
    c. Information Overload for Patient (probability reduced by 50%)
    d. Patient Busy (probability reduced by 25%)
    e. Patient Lies (probability reduced by 10%)
    f. Patient Not Cooperating (probability reduced by 10%)
    g. Patient Lack of Confirmation of Understanding (probability reduced by 75%)
    h. Confusion as to which Med is which (probability reduced by 50%)
    - **Probability decreases from .3643 to .3586 (a reduction of .0057** (1.56%)**)**
2. Office Improvement
    a. Incorrect Phone Number/Address (probability reduced to 0%)
    b. Office Forgets to Do (probability reduced by 75%)
    c. Asks Wrong Question (probability reduced by 25%)
    - **Probability decreases from .3643 to .3369 (a reduction of .0274** (7.5%)**)**
3. Combining Patient Issues and Office Improvement
    - **Probability decreases from .3643 to .3308 (a reduction of .0335** (9.2%)**)**

Fault Tree: No Prophylaxis—Probability .008258

1. Improvement in Patient Communication/Issues
    a. Patient Has Prophylaxis But Doesn't Use It (probability reduced by 75%)
    b. Patient Forgets (probability reduced by 25%)
    c. Lack of Confirmation of Understanding (probability reduced to 0%)
    d. Not Communicated at Patient Level (probability reduced to 0%)
    e. Patient Doesn't Take Paper to Pharmacy (probability reduced to 75%)
    f. Native Language Issues (probability reduced by 50%)
    g. Patient Higher Priorities (probability reduced by 75%)
    h. Patient's Lack of Confidence in Medicine (probability reduced by 25%)

i. Patient's Cultural Influences (probability reduced by 25%)
j. Patient Understands But Ignores Recommendation (probability reduced by 25%)
k.Patient's Cultural Influences (probability reduced to 25%)
l. Not Communicated at Patient Level (probability reduced to 0%)
m. Lack of Instructional Materials (probability reduced to 0 %)
n. Conflicting Info from Healthcare System (probability reduced by 25%)
o. Conflicting Info on Written Materials (probability reduced by 25%)
p. Inadequate Information about Risks and/or Seriousness (probability reduced by 25%)

- **Probability decreases from .008258 to .005028 (a reduction of .0033** (39.11%)**)**

Fault Tree: Conflict with Patient Condition—Probability .02967

1. Improvement in Patient Issues
   a. Patient Doesn't Know (probability reduced by 10%)
   b. Patient Forgets (probability reduced by 25%)
   c. Patient Forgets (probability reduced by 10%)
   d. Patient Doesn't Recognize Importance of Allergy (probability reduced by 50%)
   - **Probability decreases from .02967 to .02847 (a reduction of .0012** (4.04%)**)**
2. Shared Coverage-Improved EMR Handling
   a. Shared Coverage (probability reduced by 50%)
   - **Probability decreases from .02967 to .02602 (a reduction of .0037** (12.2%)**)**
3. Combining Patient Issues and Improved EMR Handling
   - **Probability decreases from .02967to .02481 (a reduction of .0049** (16.38%)**)**

Fault Tree: Excess Dose—Probability .01023

1. Improvement in Patient Issues
   a. Patient Uses Herbal Meds-No Information to MD (probability reduced by 50%)
   - **Probability decreases from .01023 to .009917 (a reduction of .0003** (3.06%)**)**
2. Impovement in Follow Up
   a. Failure to Follow Up (probability reduced by 25%)
   - **Probability decreases from .01023 to .009668 (a reduction of .0005** (5.49%)**)**
3. Clean Up System
   a. CPOE Offers Wrong Frequency (probability reduced to 0%)
   b. Similar Drug Names for Combos (probability reduced to 0%)
   c. Too Many Options (probability reduced by 50%)
   d. Confusion in Switching to Formulary (probability reduced by 50%)
   e. Off-label Use (probability reduced by 75%)
   f. Problems with Medication Reconciliation (probability reduced to 0%)
   g. Discharge Summary Wrong (probability reduced to 0%)
   h. Patient on Multiple Meds Leads to Complex Interaction (probability reduced by 25%)
   - **Probability decreases from .01023 to .008787 (a reduction of .0015** (14.11%)**)**
4. Combining Patient, Follow Up, and Clean Up System

- **Probability decreases from .01023 to .007917 (a reduction of .0023** (22.61%)**)**

Fault Tree: Fail to Act on Monitoring—Probability .04838

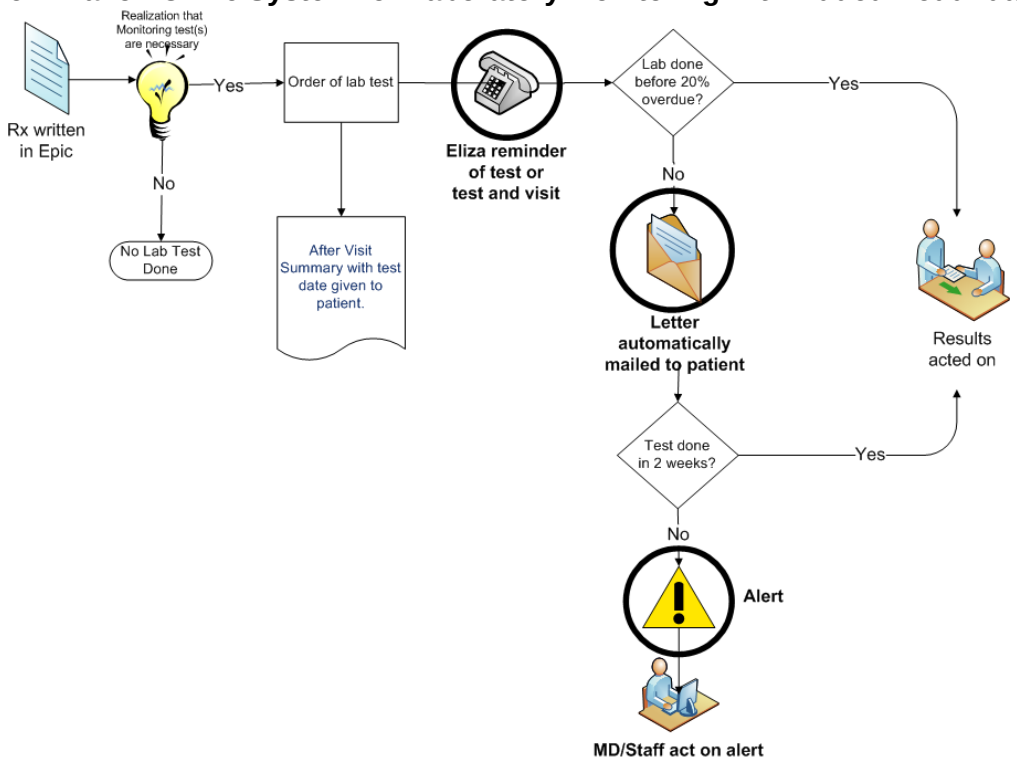
1. Coverage Issues
   a. Covering MD (probability reduced by 50%)
   b. Covering MD (probability reduced by 50%)
   c. Primary Care Physician vs Coverage (probability reduced by 50%)
      - **Probability decreases from .04838 to .0412 (a reduction of .00718** (14.84%)**)**
2. Improvement in Patient Issues
   a. No Access to Patient (probability reduced by 75%)
   b. Can't Reach Patient (probability reduced by 75%)
   c. Can't Reach Patient (probability reduced by 75%)
      - **Probability decreases from .04838 to .04329 (a reduction of .00509** (10.52%)**)**
3. Staff Issues
   a. Triages Inappropriately (probability reduced by 50%)
      - **Probability decreases from .04838 to .04592 (a reduction of .00246**(5.08%)**)**
4. Combining Coverage Issues, Patient Issues, and Staff Issues
      - **Probability decreases from .04838 to .03364 (a reduction of .01474** (30.46%)**)**

Interventions and Action Plans

As described above, several interventions were spontaneously undertaken in a bottom-up fashion during the course of the project as the teams highlighted two areas of system failure – the lack of up-to-date patient contact information and the high rate of patient "no shows" for laboratory tests. The institution by clinic staff of a system for updating patient contact information is in full flow and is consistently carried out. The establishment of the "no-show" committee led to a pilot study to clean the backlog of incompleted lab tests that has since been expanded to the entire clinic. Additional development of this system is described in the funded intervention project described below.

The primary focus of the intervention planning was directed at increasing laboratory monitoring of high-risk medications – the most common cause of serious, preventable adverse drug events and by far the most frequently occurring proximal error. We designed a set of interventions directed at increasing redundancy and improving communication:

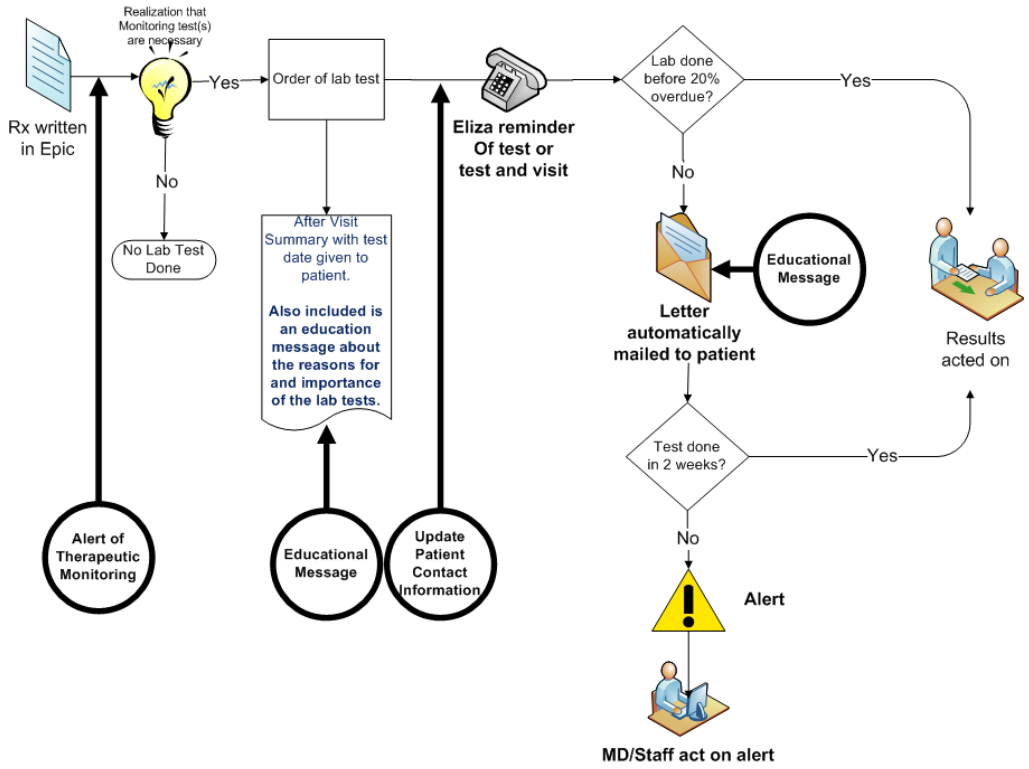
Figure 2. Fallon Clinic System for Laboratory Monitoring with Added Redundancy



Components to add redundancy:

- telephone reminders to patients about ordered laboratory tests
- mailed reminders to patients about overdue laboratory monitoring tests
- alerts to prescribers and clinic staff about patients who are overdue for laboratory tests

Figure 3. Fallon Clinic System for Laboratory Monitoring with Added Communication Components



Communication components:

- systematized updating of patient contact information
- alerts of therapeutic monitoring guidelines provided to prescribers at the time of medication prescribing, including easy ordering of laboratory tests and queries to identify special patient conditions indicating a need for laboratory monitoring
- educational messages about scheduled laboratory monitoring tests provided to patients

Each of these components is currently in process.

Conclusions and Implications

Several major themes emerged from this process. The first is the lack of redundancy in the ambulatory setting of care and the potential impact this may have on patient safety. More efforts need to be directed toward this area. Second, there is a need for better and more systematized communication within the clinic and between the clinic and patients. Third, it is not difficult to engage clinicians in a probabilistic risk assessment endeavor. The PRA process is quickly learned and is interesting for the participants, although special approaches are needed to estimate frequencies for events. Fourth, in an organization that is structured with open opportunities for bottom-up system changes, staff participation in risk assessment activities can lead directly to spontaneously generated improvements to the system.

Publications/Products

This was a planning project. Therefore, our principal product was the funded application to test the interventions we developed. In addition, we presented the process to attendees of the HMO Research Network's annual meeting in April of 2008:

Field TS, Garber L, Harrow B, chysna K, Tjia J. Using fault tree analysis and probabilistic risk assessment to improve medication safety in ambulatory care. HMO Research Network Annual Meeting; 2008 Apr 13-16; Minneapolis, MN.

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.* Mar 5 2003;289(9):1107-1116.
2. Slone Epidemiology Center at Boston University. Patterns of Medication Use in the United States 2005: A Report from the Slone Survey. *http://www.bu.edu/slone/SloneSurvey/AnnualRpt/SloneSurveyWebReport2005.pdf, accessed February 14, 2007.* 2005.
3. Royal S, Smeaton L, Avery AJ, Hurwitz B, Sheikh A. Interventions in primary care to reduce medication related adverse events and hospital admissions: systematic review and meta-analysis. *Qual Saf Health Care.* Feb 2006;15(1):23-31.
4. Sellors J, Kaczorowski J, Sellors C, et al. A randomized controlled trial of a pharmacist consultation program for family physicians and their elderly patients. *Cmaj.* Jul 8 2003;169(1):17-22.
5. Ioannidis JP, Lau J. Evidence on interventions to reduce medical errors: an overview and recommendations for future research. *J Gen Intern Med.* May 2001;16(5):325-334.
6. Raebel MA, McClure DL, Simon SR, et al. Frequency of serum creatinine monitoring during allopurinol therapy in ambulatory patients. *Ann Pharmacother.* Mar 2006;40(3):386-391.
7. Raebel MA, Carroll NM, Simon SR, et al. Liver and thyroid monitoring in ambulatory patients prescribed amiodarone in 10 HMOs. *J Manag Care Pharm.* Oct 2006;12(8):656-664.
8. 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.* Feb 2007;41(2):193-200.
9. 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.* Jan 2007;16(1):55-64.
10. Hurley JS, Roberts M, Solberg LI, et al. Laboratory safety monitoring of chronic medications in ambulatory care settings. *J Gen Intern Med.* Apr 2005;20(4):331-333.
11. Raebel MA, Carroll NM, Andrade SE, et al. Monitoring of drugs with a narrow therapeutic range in ambulatory care. *Am J Manag Care.* May 2006;12(5):268-274.
12. Raebel MA, Lyons EE, Andrade SE, et al. Laboratory monitoring of drugs at initiation of therapy in ambulatory care. *J Gen Intern Med.* Dec 2005;20(12):1120-1126.