

Grant Final Report

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Improving Safety and Quality with Outpatient Order Entry

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Abstract

Purpose: We sought to address the following three specific aims: (1) to evaluate the impact of integrating Ambulatory Computerized Physician Order Entry (ACPOE) with an advanced Clinical Decision Support System (CDSS) on important safety and quality domains in the ambulatory setting, including a) medication monitoring, b) preventive care and chronic disease management, and c) test result follow-up; (2) to evaluate the impact of integrating ACPOE with advanced CDSS on organizational efficiency, physician workflow, and satisfaction; and (3) to perform a cost-benefit analysis for the integration of ACPOE with advanced CDSS.

Scope: As part of a significant quality improvement initiative, Partners Healthcare developed an ACPOE system tightly integrated with advanced CDSS in the outpatient electronic health record known as the Longitudinal Medical Record (LMR). The system development took approximately 1 year. Study physicians worked with the Information Systems staff to develop the clinical content and convert this content into interpretable clinical decision support rules within the ACPOE system. During the initial study phase, four outpatient primary care clinics affiliated with Partners HealthCare System and utilizing the electronic health record (EHR) for at least 24 months implemented the ACPOE. The implementation phase took 8-12 weeks. To date, the ACPOE system has undergone nine software releases to add functionality or improve usability. Currently, there are seven practices using the system. Over 145,000 orders have been generated across approximately 109,000 encounters. Implementation of an EHR integrated with ACPOE and CDSS also occurred at three health centers affiliated with another institution, Atrius Health. Implementation of the EHR's full functionality occurred in stages over a 3-month period.

Methods: Each intervention, method of measurement, study design, and outcome is listed below.

Aim 1

- Actionable Reminders: Chronic disease management, preventive care, and medication monitoring delivered during the clinical encounter. Method of Measurement—EHR data of physician actions when he or she had an opportunity to perform the appropriate recommendation. Study Design—Nonrandomized, controlled trial. Outcome—Whether an opportunity was associated with appropriate action.
- Advanced Results Manager: Chronic disease management, preventive care, and medication monitoring delivered between the clinical encounter. Method of Measurement—EHR data of physician actions when he or she had an opportunity to perform the appropriate recommendation. Study Design—Nonrandomized, controlled trial. Outcome—Whether an opportunity was associated with appropriate action.
- Order Tracking: Reports of tests that were ordered but not performed. Method of Measurement—EHR data of scheduled orders and associated completion dates.

Study Design—Randomized, controlled trial. Outcome—Completion rate of tests ordered.

Aim 2

- Impact of ACPOE on clinicians' time utilization. Method of Measurement—Time-motion observations. Study Design—Pre-post. Outcome—Amount of time spent per patient before and after implementation.
- Partners Physician Satisfaction: Pre-post survey. Method of Measurement—Survey. Study Design—Pre-post. Outcomes—(1) Physicians' reported satisfaction with current workflow for testing ordering and (2) perceived impact of the ACPOE system on quality of care, patient safety, communication, and efficiency.
- Atrius Physician Satisfaction: Longitudinal survey. Method of Measurement—Survey. Study Design—Longitudinal. Outcome—Perceived impact on overall quality of care, patient safety, communication, and efficiency at 1, 3, 6, and 12 months following implementation.
- Redundant Testing Evaluation. Method of Measurement—Review of testing frequency in the outpatient setting. Study Design—Retrospective. Outcome—Percentage of the time redundant tests are performed.

Aim 3

- Cost-Benefit Analysis. In conjunction with literature review, data from Aims 1 and 2 will be used to analyze the costs and benefits of integrating ACPOE with CDSS.

Results:

Aim 1: The Actionable Reminders intervention ended on 3/31/2008, and analysis is currently underway. Implementation of the Advanced Results Manager is scheduled for Spring 2009. The Order Tracking functionality will be piloted in December 2008.

Aim 2: Following implementation, the average adjusted overall time spent per scheduled patient increased but was not statistically significant. The average adjusted "face-to-face" time spent per patient decreased slightly (0.41 minutes) but did not reach statistical significance. The Partners surveys revealed that, though many physicians agreed that the ACPOE improves the quality of patient care, a significant proportion also found the system difficult to use and a hindrance on their personal efficiency. Yet, a majority recognized the system's potentially positive impact on financial outcomes. The Atrius longitudinal survey found that the proportion of clinicians agreeing that the EHR improved quality of care, reduced medication-related errors, improved test result follow-up, and improved communication among clinicians increased. Over time, a decreasing proportion agreed that the EHR reduced the quality of patient interactions, resulted in longer patient visits, and increased time spent on medical documentation.

Aim 3: The cost-benefit analysis requires data and analysis from Aim 1 and Aim 2; therefore, results are not yet available,

Key Words: Ambulatory Care Information Systems, Clinical Decision Support Systems Medication Systems, Reminder Systems, Drug Monitoring, Preventive Health Services, Time and Motion Studies, Efficiency, Cost-Benefit Analysis

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Final Report

Purpose

This study aims to define the value proposition of integrating clinical decision support systems (CDSS) into an ambulatory computerized physician order entry (ACPOE) system. The three specific aims of the study are:

1. To evaluate the impact of integrating ACPOE with advanced CDSS on important safety and quality domains in the ambulatory setting, including a) medication monitoring, b) preventive care and chronic disease management, and c) test result follow-up.
2. To evaluate the impact of integrating ACPOE with advanced CDSS on organizational efficiency, physician workflow, and satisfaction.
3. To perform a cost-benefit analysis for the integration of ACPOE with advanced CDSS.

Scope

Background

The US healthcare system continues to face enormous quality, safety and cost challenges. Although healthcare spending now accounts for 15% of the annual GDP, markers of healthcare quality in the US continue to lag behind those of other industrialized countries. Many of these challenges occur in the ambulatory setting. Quality gaps that are particularly relevant in the ambulatory setting include a high incidence of adverse drug events and lack of compliance to established guidelines for preventive care, chronic disease management, and test result follow-up. To achieve a ‘quantum leap’ in quality improvement, we must help physicians make better decisions.

Two forms of healthcare information technology (HIT), clinical decision support systems (CDSS) and ambulatory computerized physician order entry (ACPOE), have been touted as powerful and sustainable interventions to address these quality concerns. Our work and that of others have shown that computerized decision support in the form of alerts and reminders can improve outcomes and reduce costs in the inpatient setting. However, doubts continue to exist about the efficacy of these systems in the ambulatory setting, especially when they exist in isolation. For example, trials evaluating CDSS have not consistently yielded positive results, and the magnitude of their effects is somewhat limited, with room for improvement. Though good evidence exists to demonstrate the impact of inpatient computerized physician order entry (CPOE), the impact of ACPOE has not been well studied. Moreover, the adoption of CDSS and ACPOE systems remains slow, and their value proposition remains uncertain. Prior work suggests that CDSS systems work best when they are speedy and well integrated into clinicians’

workflow. Therefore, tight integration of CDSS with ACPOE is a promising strategy to improve quality and efficiency in the ambulatory setting. When ACPOE is linked with advanced CDSS, clinicians can be prompted at various points during their workflow about the desirable course of action *and* simultaneously be given the opportunity to execute the action (by ordering it) with minimal effort. We hypothesized that the value of ACPOE integrated with advanced CDSS lies not only in improved medication safety and guideline compliance but also in improved efficiencies for the individual provider and the healthcare system. We further hypothesized that the overall value added by these systems outweighs their costs.

Context

At the start of the study, there were 1,455 primary care physicians (PCP) and staff in sites that used the institution's home-grown EHR. The BWH clinic network takes care of approximately 72,000 adult patients making 235,000 visits per year, and the MGH clinic network takes care of approximately 185,000 adult patients making 380,000 visits per year. Analysis of the coded problems in the LMR patient database revealed that 12% have hypertension, 2.7% have diabetes, and 3.2% have some form of coronary artery disease. During the study phase, four clinics opted to implement the outpatient order entry system integrated with decision support.

Three health centers at Atrius Health implemented an EHR with ACPOE integrated with CDSS. The implementation process occurred over a 3-month period.

Settings

The proposed study was conducted in adult outpatient clinics affiliated with the Brigham and Women's Hospital (BWH) and Massachusetts General Hospital (MGH). All clinics have been active users of our EHR, the Longitudinal Medical Record (LMR), for at least 24 months. These clinics represent a diverse array of hospital-based and community-based clinics and take care of patients from a broad spectrum of socioeconomic backgrounds.

Atrius Health is an integrated, multispecialty group practice with approximately 250 primary care physicians caring for 500,000 patients across 19 ambulatory health centers throughout eastern Massachusetts.

Participants

Inclusion criteria included all primary care physicians and nurse practitioners practicing in adult BWH or MGH outpatient clinics. Clinicians eligible for inclusion in the Atrius longitudinal survey were defined as those primary care clinicians practicing at one of the three health centers at the time of initial implementation of the electronic health record.

Incidence and Prevalence

Not applicable.

Methods

Aim 1

Actionable Reminders. Chronic disease management, preventive care, and medication monitoring are delivered during the clinical encounter. The institution previously implemented a patient-specific electronic clinical reminder system to improve rates of appropriate care for preventive medicine services and chronic disease management (Table 1) and to increase the rate of appropriate laboratory monitoring for patients receiving high-risk medications (Table 2). The reminders are displayed within the main patient summary screen of the electronic health record system alongside patient problem lists, medication lists, and allergy lists. When appropriate, the same decision support is presented as an alert when the physician writes the prescription for the first time or renews it.

We hypothesized that the integration of ACPOE with these reminders would further facilitate physician ordering of necessary laboratory tests and medications. These ACPOE-enabled reminders allowed physicians to immediately order the suggested lab tests and medications by clicking the button associated with the suggestion. Once the physician has clicked this button, the ACPOE system automatically generated the medication prescription or the appropriate laboratory requisition slip.

Physicians in the intervention arm during phase 1 had access to these ACPOE-enabled reminders, and physicians in the control arm had access to reminders and alerts that are not directly linked to the ACPOE module.

Table 1. Reminders for preventive care and chronic disease management

Decision Support Tool	Intervention (α =during visit; β =between visits)
I. Preventive care Reminders: Mammography	α
I. Preventive care Reminders: Pneumococcal and Influenza Vaccinations	α
I. Preventive care Reminders: Cholesterol screening	α
II. Chronic Disease Management Reminders and Guidelines: CAD—Beta blocker and aspirin use	α
II. Chronic Disease Management Reminders and Guidelines: CAD and elevated LDL—measure LDL if not measured, and start or increase statin	α/β
II. Chronic Disease Management Reminders and Guidelines: DM—Hba1c not measured or not in range—measure HbA1c and intensify therapy	α/β
II. Chronic Disease Management Reminders and Guidelines: DM and concurrent hypertension or microalbuminuria—start or increase ACE Inhibitor	α/β
II. Chronic Disease Management Reminders and Guidelines: DM and elevated LDL—start or increase statin	α/β
II. Chronic Disease Management Reminders and Guidelines: Chronic Renal Disease and concurrent Hypertension—start ACE inhibitor	α
II. Chronic Disease Management Reminders and Guidelines: Chronic Renal Disease and anemia—rule out iron deficiency	α/β
II. Chronic Disease Management Reminders and Guidelines: Chronic Renal Disease and Iron deficiency—replete iron	α/β

Table 2. Medications requiring monitoring by type of laboratory test

Renal Function	Thyroid Function	Liver Function	Drug Levels	Electrolytes	Complete Blood Count
Metformin, NSAIDS, Cyclosporine, ACE Inhibitors, Allopurinol, Azathioprine, Ganciclovir, Procainamide	Amiodarone Thyroxine Lithium	Amiodarone Statins	Carbamazepine Cyclosporine Phenytoin Valproate	Diuretics Digoxin ACE Inhibitors K ⁺ Supplements	Clozapine Procainamide Quinidine Ganciclovir

The unit of analysis was the opportunity for a physician to order the appropriate laboratory test or medication. This was defined by the firing of a reminder or alert in the intervention group. If multiple medications require monitoring action, then they were considered separate opportunities. For the control group, these opportunities were defined by times when the reminder or alert would have fired, had the physician been in the intervention group. We captured these potential firings of the reminders and alerts in real time in the control group, even though we did not present them to the physician. Our primary outcome was whether an opportunity was associated with appropriate action within 14 days of the visit. As a secondary outcome, we measured the time to appropriate monitoring action following the firing of the reminder.

Advanced Results Manager: Chronic Disease Management, Preventive Care, and Medication Monitoring Delivered between the Clinical Encounter. Physicians will be alerted when laboratory markers of chronic disease management (e.g., high HbA1c for patients with diabetes or iron deficiency in patients with renal insufficiency) indicate the need for further intervention.

These alerts will receive higher priority than slightly abnormal test results or normal test results in the LMR Results Manager (RM). When physicians review these test results, the system will prompt them to perform certain appropriate actions, including adjusting existing medications or scheduling further tests. Once confirmed, the ACPOE module will execute them. At the request of the clinician, the system can also automatically generate letters to patients explaining changes in the therapeutic plan.

To determine the combined effect of interventions for Actionable Reminders and Advanced Results Manager, we defined a secondary outcome as whether the combined opportunity (i.e., triggering of reminders during the visit or the arrival of test results between visits) was associated with the appropriate action.

For medication monitoring (between visits), physicians are alerted when new lab data necessitate medication adjustment and facilitate adjustment. The opportunity to perform the appropriate monitoring action in this intervention is defined as the arrival of a test result that requires medication adjustment or repeat testing. Our primary outcome for this intervention is whether an opportunity was associated with appropriate monitoring actions within 28 days. The secondary outcome is the time to appropriate monitoring action following the arrival of the index lab result.

Physicians also are alerted about abnormal test results that require further actions or follow-up, provide guidelines, and facilitate action. For example, for a patient with first incidence of TSH=7.4, the physician gets prompted to order a complete thyroid panel.

We defined the primary outcomes in a manner similar to the other domains, with the unit of analysis being the opportunity for a physician to order the appropriate laboratory test or medication.

The primary outcome will be whether an opportunity was associated with the appropriate action. To determine the combined effect of interventions, we will again define a secondary outcome as whether the combined opportunity (i.e., triggering of reminders during the visit or the arrival of test results between visits) was associated with the appropriate action.

Order Tracking: Reports of Tests that Were Ordered but not Performed. The intervention is a new Order Tracking report function in LMR, which tracks new orders for laboratory tests and colonoscopies and produce reports viewable by physicians, practice managers, and the Research Assistant for study purposes. Reports of orders entered by a clinician but not completed, such as labs not drawn within 2 weeks or missed and unscheduled colonoscopy appointments, will be generated monthly and available thereafter for viewing in the existing Reports Central application.

The laboratory tests include basic metabolic panels, thyroid stimulating hormone, complete blood count, cholesterol panels, and hemoglobin A1C. Screening and diagnostic colonoscopies generate separate patient letters. Tests were selected for high clinical impact if missed, such as colonoscopy, electrolyte abnormalities, or changes in renal function, or as markers of high test frequency.

The study is being conducted in four of the satellite clinics affiliated with the Brigham and Women's Hospital (BWH) Network, all of which have been active LMR users for at least 24 months. The first month of the intervention period is scheduled for January 2009 and will be an acclimatization or "burn-in" period, when no data will be collected. The data collection period will then begin, with Order Tracking reports updated monthly in Reports Central. The Research Assistant (RA) has primary responsibility for running the Order Tracking reports, generating a reminder letter to the patient, and emailing the responsible clinician and practice assistant.

The Research Assistant's role is for proof-of-concept study purposes. If we find improved outcomes, our secondary aim will be to integrate the Order Tracking application from Reports Central into LMR's Results Manager, thereby electronically facilitating patient notification and eliminating the need for this role. This design is driven by the fact that Reports Central is a data-gathering application; subsequent integration with Results Manager then enables follow-up letters and documentation capability but requires further software development.

This is a non-blinded, cluster-randomized, controlled trial comparing proportions of test completion among participating practices. To date, four practices with EOv capability are participating in the study. The unit of analysis will be a single test ordered by a single clinician. Cluster randomization will be at the physician level, with half the physicians within a practice randomized to receive the intervention of RA follow-up and half continuing with standard care, which will be the control group. At the end of the study, intervention physicians will be surveyed about satisfaction with receiving information about missed tests. Data from the 6-month period prior to the intervention will be used to perform a baseline assessment of the proportion of tests ordered that were actually completed within the relevant timeframe.

The primary outcome will be the proportion of completed tests in the intervention group compared with the control group. Secondary outcomes will compare test type, specifically lab tests versus colonoscopies. Patient demographics and physician volumes and characteristics will be collected and used in the analysis to control for confounding.

Aim 2

Impact of ACPOE on Clinicians' Time Utilization. Time-motion studies were performed on primary care practitioners to assess the impact of ACPOE on clinician workflow and time. To achieve this, clinicians were observed 6 months prior to ACPOE implementation and then again 6 months after. Comparing the time spent on activities before and after implementation was used to see the impacts of the technology versus on-paper ordering and billing.

The time-motion observations were performed by trained observers, and the activities of the clinician were recorded using a Microsoft Access data collection form on a touch-screen tablet PC. The list of activities/categories was validated through pilot observation sessions. Up to two simultaneous activities could be captured, and timestamps associated with these activities were added to the database to capture the time spent.

Observations were performed on primary care clinicians at four primary care clinics, and, when possible, clinicians were observed both before and after ACPOE implementation. Both pre- and post- observations were conducted for 4-8 hours (equivalent to 1-2 clinic sessions).

For analysis, activities were categorized as Direct Patient Care, Indirect Patient Care, Administration, and Miscellaneous. The main outcome measure was time spent per patient before and after implementation. A mixed model was used to model time spent per patient as a function of the main covariate, a binary indicator of pre- vs. post-implementation. The mixed model also accounted for the random effects of physicians and observers.

Physician Satisfaction: Pre-post Survey. At baseline, we used a survey to determine physician satisfaction with the current workflow for test ordering and billing.

To assess clinicians' attitudes toward the ACPOE, we distributed a survey to clinicians who had been using the application for at least 6 months. The survey was used to determine physicians' satisfaction with the new workflow, whether they agreed or disagreed with the content of the decision support, and what factors may impede their ability to use the application. We assessed physician attitudes regarding the application in general, the speed of the system, the value of alerts and reminders, and the impact on workflow. Clinicians also reported which features were felt to be most valuable and how frequently the system was used.

Physician Satisfaction: Longitudinal Survey. A survey was conducted at three Atrius Health clinics, an integrated multispecialty group practice, to evaluate longitudinal changes to clinicians' attitudes toward an EHR. Each of these practices transitioned from paper record systems to the Epic EHR.

Surveys were distributed to 86 primary care clinicians 1 month (baseline), 3 months, 6 months, and 12 months after the implementation of the EHR. All rounds of the survey included eight individual items exploring the perceived impact of the EHR on four domains of healthcare: 1) overall quality of care, 2) patient safety, 3) communication, and 4) efficiency. Respondents rated this impact on a five-point Likert scale from "very positive" to "very negative."

Redundant Testing Evaluation. The research team converted vendor-purchased redundant testing information into interpretable rules. These rules are the basis of an analysis to determine the baseline rates of redundant testing and the potential cost savings that could be achieved if redundant testing decision support rules were incorporated into order entry.

The study hypothesis is that (1) a significant amount of redundant testing occurs in the outpatient setting and (2) a potential cost savings could be achieved if a percentage of these unnecessary tests was eliminated.

Our analysis is prioritized so that we will first apply rules that are simple and unambiguous (i.e., rules that don't require looking at the diagnosis, problem list, etc., to determine whether there are variations in the proper test frequencies). We will consider a second phase of the study that will include the more complex scenarios (e.g., test x should be done no more than once every 3 months if the patient is diagnosed with y, but every month if diagnosed with y & z).

The analysis of the potential cost savings will involve applying the rules set to the patient data and seeing what percentage of the time redundant tests are done. The redundant test rate can then be multiplied by the rate at which alerts are accepted to determine what percentage of these tests could be avoided. The rate of potentially eliminated tests can be multiplied by the amount of money spent on these redundant tests, producing the cost-savings number. Another step may involve analyzing the reasons for reimbursement rejections and assessing the monetary impact.

We anticipate this study will be of great interest for the potential beneficiaries of the cost savings, particularly payers and hospitals. Hospitals that have systems in place to protect against unnecessary, expensive redundant tests may be able to negotiate better contracts with payer. Hospitals considering such systems will be better able to evaluate the cost-benefit.

Aim 3

Cost-Benefit Analysis. The costs and benefits of integrating ACPOE with CDSS are currently being analyzed. The analysis is being conducted using data from the previous two aims. To the extent possible, the costs and benefits of this technology are being examined from two perspectives: (1) the healthcare organization and (2) society as a whole.

Several benefits and costs are easily quantified in financial terms based on data collected in the study. These include decrements in rejected claims, cost of software development, and impact on physician workflow.

To monetize improvements in safety and quality (from Aim 1) benefits, we are relying on published sources in the medical literature. We are leveraging the chronic disease management cost-benefit analysis performed by the Center for Information Technology Leadership. The major domains of costs and benefits that will be included in the CBA are outlined below.

Major Components of Cost-Benefit Analysis.

- Direct Capital and One-time Costs
 - Information Systems (IS) labor costs:
 - Costs of developing 'EOV' and integrating with current IS systems
 - Initial IS staff training time
 - Physician labor costs for initial training (e.g., training hours, number trained, management hours, planning training)

- Direct Operating and Maintenance Costs
 - IS labor costs
 - Physician labor costs for recurring training
 - Incremental costs for tests that are performed because of better physician compliance to guidelines and patient compliance to therapeutic plan
- Indirect Costs and Savings: Physician time impacts: incremental time responding to alerts, ticklers, templates, and guidelines. Indirect costs are all essentially recurring costs, composed primarily of effects on labor productivity. Data collected during the time-motion studies under Specific Aim 2 will be used to account for the financial impact of this technology on workflow.
- Benefits
 - Improved medication monitoring to improve medication safety
 - Improved preventive care and chronic disease management
 - Improved test result follow-up
 - Avoided unnecessary tests and/or prescriptions
 - Revenue enhancement from reduction in rejected claims
 - Cost savings from reduced need to research and resubmit rejected claims

Limitations

Study findings should be interpreted in the context of the study design. The evaluation performed at Partners HealthCare consisted of primary care clinicians affiliated with one umbrella organization and utilizing a home-grown EHR. It is possible that the results may not generalize to all settings or systems. Similarly, the Atrius EHR implementation occurred within a single health network that devoted significant resources to the implementation process. It is possible that the implementation process impacted our findings.

Results

Aim 1

Actionable Reminders: Chronic Disease Management, Preventive Care, and Medication Monitoring Delivered During the Clinical Encounter. The Actionable Reminder Intervention was completed on 3/31/2008. We allowed for a 1-month follow-up and are currently completing data collection. Preliminary analysis will be performed in January 2009, and an abstract will be submitted for presentation at the Society for General Internal Medicine Annual Meeting in May 2009. Manuscript preparation will follow and submitted for publication.

Advanced Results Manager: Chronic Disease Management, Preventive Care, and Medication Monitoring Delivered Between the Clinical Encounter. The functional and technical specifications were completed in early 2008. However, due to a major enterprise architecture initiative, development was on hold until November 2008. Coding was estimated at 6-8 weeks, and the functionality will go live with the next major EHR release in spring 2009. The following reminders are being evaluated:

- Abnormal Result Follow-up
 - Elevated glucose for patients without known diagnosis of diabetes
 - Abnormal TSH for patient without known diagnosis of thyroid disease
 - New anemia
 - New abnormal MCV
- Medication Monitoring
 - Elevated creatinine and taking a med that may cause renal dysfunction
 - Elevated creatinine and taking a med that may be affected by renal dysfunction
 - Elevated potassium and taking a med that may raise potassium
 - Elevated ALT and taking a statin
 - Abnormal TSH and taking thyroid hormone
- Chronic Disease Management
 - Hypercholesterolemia

- ACE-I/ARB in Chronic Kidney Disease

Order Tracking: Reports of Tests That Were Ordered But Not Performed. The Order Tracking Reports are currently in development, and the intervention is expected to begin in January 2009.

Extensive programming was required to create new reports. Below is a list of the most important developments that have been implemented through combined efforts with the research and Partners Information System teams:

- New reports have been created to generate lists of patients with labs and colonoscopies that have been ordered but that have not been done. For most labs, except lipids, the applicable timeframe is within 30 days; for colonoscopies, within 60 days. The data can be exported to research databases and the LMR for the generation of batched patient letters.
- Added logic to separate screening colonoscopies (those ordered for routine age appropriate testing) from diagnostic colonoscopies (those ordered based on symptoms or personal or family history).

Aim 2

Impact of ACPOE on Clinicians' Time Utilization. Before ACPOE implementation, 15 clinicians were observed, treating 193 patients. Fifteen clinicians were observed after ACPOE implementation, treating 137 patients. Twelve clinicians were observed both before and after implementation.

Following implementation, the average adjusted overall time spent per scheduled patient increased 2.05 minutes ($p = 0.21$), from 27.60 (SE = 2.79) before ACPOE to 29.79 minutes (SE = 2.91) after ACPOE. The average adjusted "face-to-face" time spent per patient decreased 0.41 minutes ($p=0.76$), from 16.62 (SE = 1.78) before ACPOE to 16.21 minutes (SE = 1.89) after ACPOE. The time spent on major analysis categories (only face-to-face time) is summarized below:

Table 3.

	Average Adjusted Minutes per Patient (SE): Pre-ACPOE	Average Adjusted Minutes per Patient (SE): Post-ACPOE	Estimate of change	p value
Direct Patient Care	10.92 (1.27)	11.35 (1.35)	0.42	0.66
Indirect Pt. Care: Write	3.35 (0.47)	3.03 (0.49)	-0.32	0.33
Indirect Pt. Care: Read	0.97 (0.15)	0.91 (0.15)	-0.06	0.66
Indirect Pt. Care: Other	0.66 (0.14)	0.29 (0.15)	-0.37	0.004
Administration	0.16 (0.03)	0.19 (0.04)	0.03	0.45
Miscellaneous	0.50 (0.10)	0.54 (0.10)	0.04	0.69

The data suggest that the ACPOE implementation did not significantly impact the duration of time spent in clinic and time spent face-to-face with patients. Compared with before ACPOE, the distribution of time spent in major activities also did not significantly change after ACPOE.

Additional analysis is underway to examine the impact on specific clinician clinic activities that occur between patient visits.

Partners Physician Satisfaction (Pre-post Survey): Pre-survey. The response rate for the baseline survey was 55% (144/261). The survey revealed that 52% of PCPs did not have a system to keep a record of test results, 62% did not have a system to detect a missed ordered test, and 32% of PCPs were not satisfied with how they managed test results. Physicians who had a system for detecting a missed test were equally satisfied compared with those who did not; 70% of PCPs agreed they spent too much time filling out forms; 58% agreed that they don't spend enough time with each patient; 56% were concerned that they would lose money if they ordered tests incorrectly; 43% strongly agreed or agreed that ACPOE would slow them down. Only approximately one third of physicians strongly agreed or agreed with the potential value of ACPOE features.

ACPOE addresses common physician concerns, such as test tracking and notification of missed tests. However, physicians were concerned about the impact of ACPOE on workflow and the value of its features, and these concerns will need to be addressed to ensure acceptance.

Twenty-five physicians met the survey criteria of having had 4 months of access to ACPOE integrated with decision support. All 25 physicians completed the survey, for a response rate of 100%.

Partners Physician Satisfaction (Pre-post Survey): Post-survey. A majority of physicians (79%) were "satisfied" or "very satisfied" with initial training, and 62% were satisfied or very satisfied with ongoing support after go-live. Although 40% of physicians did not find the application difficult to use, 28% agreed or strongly agreed that the application was difficult to use. Perceptions on whether the application increased personal workflow varied: 36% of physicians found that the application increased workflow efficiency, 32% disagreed or strongly disagreed, and 32% were neutral. Similarly, 32% felt the application slowed them down, whereas only 16% disagreed with this statement (52% were neutral). The majority of physicians were uncertain whether the system improved the quality of patient care (56% neutral and 4% disagreed). However, 56% of physicians agreed that the application improved communication between themselves and their staff (40% were neutral). Many physicians recognized the positive financial impact of the system: over half (52%) reported that the application improved the practice's ability to bill for all services rendered (40% were neutral), 28% felt that their own earning potential improved (56% were neutral), and 20% agreed that revenue for the entire practice improved (68% were neutral).

Physician Satisfaction: Longitudinal Survey. Response rates at months 1, 3, 6, and 12 were 92%, 95%, 90% and 82%, respectively. Results reported below describe changes in perception from month 1 to month 12.

The proportion of clinicians agreeing that the EHR improved quality of care increased (63% to 86%; $p < 0.001$). The proportion of clinicians who agreed that the electronic health record reduced medication-related errors (72% to 81%, $p = 0.03$) and improved follow-up of test results (62% to 87%, $p < 0.001$) also increased. An increasing proportion of respondents agreed that communication among clinicians improved (72% to 93%, $p < 0.001$), and a decreasing proportion reported a worsening in the quality of patient-physician interactions (49% to 33%, $p = 0.001$).

The proportion of clinicians agreeing that the electronic health record resulted in longer patient visits decreased (68% to 51%, $p = 0.001$). Fewer clinicians agreed that time spent on medical documentation outside of clinical sessions increased (78% to 68%, $p = 0.006$). At baseline, 92% of clinicians felt that the electronic record improved access to clinical information, and this proportion did not change significantly from month 1 to month 12.

Though clinicians may perceive some initial problems with a new EHR, they become significantly more receptive to it within 1 year of implementation. Within 1 year of the implementation of the record, a vast majority of clinicians felt that it improved overall quality, patient safety, communication among clinicians, and access to clinical information.

Redundant Testing Evaluation. The research team is currently performing an analysis to determine the baseline rates of redundant testing and the potential cost savings that could be achieved if redundant testing decision support rules were incorporated into order entry. Although this decision support was not implemented during the grant, we anticipate that our findings will motivate the institution and others to utilize such decision support. We anticipate that preliminary analysis will be completed in January 2009 and an abstract will be submitted to the Society for General Internal Medicine's 2009 Annual Meeting. We are looking forward to completing the analysis and manuscript in the coming months.

Aim 3

Cost-Benefit Analysis. The cost-benefit analysis requires data and analysis from Aim 1 and Aim 2; therefore, results are not yet available.

Significance

This study makes an important contribution to the evidence supporting ACPOE linked to CDSS. Following completion of our analyses in the months ahead, we expect to demonstrate the impact of the technology on outpatient quality and safety. We anticipate that the findings will help overcome barriers in meeting quality and safety guidelines in the outpatient setting. Our study also addresses key issues on satisfaction, workflow, and cost-benefit. These evaluations address how to effectively provide decision support to clinicians while helping physicians and healthcare organizations assess the risks and benefits of investing in such systems.

Implications

Analyses completed thus far demonstrate that ACPOE linked to CDSS shows great promise in improving safety and quality in the outpatient setting. There is some variation in the perceived impact on efficiency. We anticipate that findings from the completed study will support clinicians and health system leaders implementing this technology.

List of Publications and Products

The following publications and presentations are products of this grant. We plan to submit additional findings once our final analysis is complete.

Manuscript

El-Kareh R, Gandhi TK, Poon EG, Newmark LP, Ungar JP, Lipsitz S, Sequist TD. Trends in Primary Care Clinician Perceptions of a New Electronic Health Record. Submitted for publication.

Presentations and Abstracts

Matheny ME, Poon EG, Gandhi TG. Evaluation of Guideline Compliance after the Implementation of a Clinical Decision Support and Computerized Physician Order Entry System for Medication Laboratory Monitoring. Annual PBRN Conference 2005.

Gandhi TK, Poon EG, Sequist TD et al. Primary Care Clinician Attitudes Towards Ambulatory Computerized Physician Order Entry. AMIA Annual Symposium 2005.

El-Kareh R, Gandhi TK, Poon EP, Newmark LP, Ungar J, Orav EJ, Sequist TD. Trends in clinician perceptions of a new electronic health record. 2008 SGIM 31st Annual Meeting.

Ungar JP, Gandhi TK, Poon EG, Manasson J, Yoon C, Orav EJ, Johnson R, Newmark LP. Impact of Ambulatory Computerized Physician Order Entry on Clinicians' Time. AMIA Annual Symposium 2008.

El-Kareh R, Gandhi TK, Poon EP, Newmark LP, Ungar J, Orav EJ, Sequist TD. Trends in clinician perceptions of a new electronic health record. AMIA Annual Symposium 2008.

Siegel LC, Housman D, Newmark L, Ungar JP, Einbinder JS, Gandhi TK. Linking test ordering with order tracking: closing the loop in ambulatory care. AMIA Annual Symposium 2008.