

Grant Final Report

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**Evaluating Smart Forms and Quality Dashboards
in an EHR**

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Abstract

Purpose: 1. To design and implement an integrated documentation-based clinical decision support and physician feedback system, provided in an electronic health record (EHR), to improve the management of patients with acute and chronic medical conditions. This study focused on three conditions - acute respiratory tract infections (ARI), coronary artery disease (CAD) and diabetes mellitus (DM). 2. To assess the perceived value of EHR quality dashboards by clinicians and their marginal impact over smart forms on compliance with best practices in ARI and CAD.

Scope: Smart Forms integrate decision support into clinical documentation templates, thus facilitating clinical decision support, ordering, and patient education. The current version of the Smart Form is designed around two clinical areas: acute respiratory tract infections (ARI) and coronary artery disease (CAD)/diabetes mellitus (DM). A second application we developed was the Quality Dashboards (QD). Quality Dashboards track statistical data about patient care, in order to evaluate how closely clinicians follow guidelines on best practices. They are also meant to display patient data in order to track and benchmark physician and practice performance against other physicians and practices, within a specified community. Smart Forms and Quality Dashboards were introduced to as many as 27 Partners affiliated primary care clinics and were used by over 400 clinicians in the course of a randomized control study.

Methods: Smart Forms and Quality Dashboards were designed and developed by the research team in conjunction with Partners software developers. Four Randomized Control Trials (RCT) randomized by practice were conducted that compared usual care, use of Smart Forms alone, and use of Smart Forms plus Quality Dashboards. A smaller scale pilot preceded three out of four trials to assess feasibility. The pilot users were asked to fill out a survey following the pilot and major barriers were addressed prior to each large-scale RCT. The difference between the intervention practices and control practices served as the outcome measures. In addition, we identified and addressed clinician and system barriers to the effective use of Smart Forms. Statistical software packages SUDAAN and SAS were used to analyze the data.

Results: ARI Smart Form study revealed a small but significant difference in antibiotic prescribing rates. In the intent-to-intervene analysis, clinicians prescribed antibiotics to 43% of patients with ARI diagnoses in control clinics and to 39% of patients with ARI diagnoses in intervention clinics. Usage data from the ARI QD pilot indicates that pilot users accessed the application to run reports to see how he or she performed on antibiotic prescription rates compared to his or her practice peers and against national benchmarks. Pilot data also indicated that clinicians found the ARI QD with information on diagnoses and levels of service billing data comparisons integral to understanding practice patterns for ARI. CAD/DM Smart Form RCT ran for 310 days and involved 239 physicians and during over 26,000 visits. All measures data has been collected and is presently in final stages of analysis. CAD/DM Smart Form pilot suggested a trend towards improved participants' satisfaction with their management of smoking, ACE I/ARB use, and especially diet and exercise, but these differences were not statistically significant. In the post-pilot usability survey, the majority of participants agreed that the

CAD/DM Smart Form helped them to improve compliance with clinical guidelines and improve the quality of patient care. CAD/DM QD RCT was conducted with 15 primary care clinics (8 in the intervention group and 7 in control). All measures data for the study was retrieved by May, 2009 and is being analyzed. Results from the user survey indicate that exposure to new CDS even without actual use may marginally increase adherence to the clinical guidelines.

Key Words: coronary artery disease, Diabetes Mellitus, acute respiratory tract infections, clinical decision support, smart form, quality dashboard

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Final Report

Purpose

This research project was funded to evaluate documentation-based clinical decision support and quality dashboards through the following three project aims.

Aim 1. To design and implement an integrated documentation-based clinical decision support and physician feedback system, provided in an electronic health record (EHR), to improve the management of patients with acute and chronic medical conditions.

Hypothesis 1. A documentation-based clinical decision support tool (CDSS) “smart form”, and a “quality dashboard” physician feedback system, can be designed and implemented to facilitate documentation and physician order-entry, provide individualized, evidence-based recommendations for the management of patients with coronary artery disease (CAD) and acute respiratory tract infections (ARIs), and are usable by primary care physicians.

Aim 2. To determine the effectiveness of documentation-based CDSS and physician feedback on documentation and the clinical management of patients with coronary artery disease and acute respiratory tract infections.

Hypothesis 2A. A documentation-based CDSS “smart form” will increase the documentation of important clinical data in patients with CAD and ARI when compared to usual practice.

Hypothesis 2B. A documentation-based CDSS “smart form” will increase adherence with guidelines for the management of patients with CAD and ARI when compared to usual practice.

Aim 3. To assess the perceived value of EHR quality dashboards by clinicians and their marginal impact over smart forms on compliance with best practices in ARI and CAD.

Hypothesis 3A. An EMR-based “quality dashboard” system will provide additional benefit over documentation-based CDSS “smart form” in the management of patients with CAD and ARI.

Hypothesis 3B. Barriers to the effective use of computer-based quality improvement strategies can be identified.

Scope

Computer-based clinical decision-support systems (CDSS) are health information tools that combine education, physician participation, and feedback via reminders. These information technologies have the potential to change physician behavior at the precise time that clinical decisions are being made. However, such systems are still not used broadly and the full potential of CDSS remains to be tested. Moreover, when computerized reminder systems have resulted in demonstrable improvements, often this improvement has been less than anticipated.

Issues of usability and integration into the clinicians' workflow are two most important barriers to the effectiveness of CDSS. One potential solution under development at Partners Healthcare is to integrate decision support into clinical documentation templates, thus facilitating clinical decision support, ordering, patient education, and documentation in a single step. We believe that Smart Forms (SF) have the potential to increase the perceived value and impact of EHRs for end-user physicians.

Direct feedback to physicians regarding the quality of care they provide has also been shown to be significant for improving guideline adherence. Documentation-based CDSS facilitates the acquisition of key quality data, which can then be presented in an efficient and concise manner in a Quality Dashboard (QD). In addition, such Quality Dashboards, linked to the electronic medical records, can enhance feedback by providing actionable, population-based information on quality of care, adherence to guidelines in relation to local and national benchmarks, and identify patients most in need of attention.

However, to date, very few EHRs have developed such features and functions. Of those that might have these tools, few institutions have taken advantage of these features or have systematically tested them. . We, therefore, designed, developed and implemented Smart Forms and Quality Dashboards in over 20 primary care practices in the Partners Health Care system with over 400 clinician study participants. These tools provided clinical decision support in three clinical areas – ARI, CAD, and diabetes. We then analyzed their effect on quality of care and adherence to guidelines using a randomized control trial strategy.

Methods

Subject Characteristics and Enrollment

Study subjects included patients seen at a number of outpatient primary care practices associated with Brigham and Women's and Massachusetts General Hospitals. Number of participating practices varied somewhat depending on the stage of the study, from 10 to 27. All attending and resident physicians in a given practice were included in the study. Patient population consisted of patients who made at least one visit to the clinic during the study period. The study consisted of two cohorts, one for ARI and one for CAD. The CAD cohort included patients with a diagnosis of coronary artery disease, younger than age 85, registered in the practice for at least one year, not living in a nursing home or with metastatic cancer. The ARI cohort included patients with a billing diagnosis of non-specific upper respiratory infection, otitis

media, sinusitis, pharyngitis, acute bronchitis, pneumonia, or influenza. There were no age limits on the ARI cohort.

Procedures

Prototypes of the Smart Forms and Quality Dashboards were developed and systematically tested with Partners physicians using a portable testing lab and the Questionnaire for User Interface Satisfaction (QUIS). Then, preliminary versions of the interventions were pilot tested in Partners practices for 6-8 weeks to prove feasibility, handle logistical issues, and conduct an informal “before-and-after” test of effectiveness. Feedback was used to optimize the interventions. Finally, a controlled trial, randomized by practice, was conducted in 27 Partners ambulatory primary care practices that use the LMR, comparing usual care, use of Smart Forms alone, and use of Smart Forms plus Quality Dashboards (See Table 1 for pilot and RCT dates). Detailed usability surveys were given to physicians post-intervention to identify barriers to the use of these interventions. The data were also used to correlate different aspects of usability, actual use of the systems (measured by capturing screen navigation data), and their effectiveness in improving documentation and quality of care.

Physicians in the clinics randomized to the interventions were alerted to the introduction of the Smart Forms and Quality Dashboards through regular email announcements about LMR enhancements. Additionally, physicians in the intervention clinics were trained to use the Smart Forms in an in-person educational sessions at each clinic ~3 weeks prior to the beginning of the intervention period. Physicians in control clinics continued using an existing clinical decision support tool – End Of Visit (EOV) during the study period.

Table 1. Study timelines

	Pilot Start	Pilot End	Participant practices	RCT Start	RCT End	Participant practices
ARI SF	8/29/2005	9/10/2005	16	11/3/05	5/31/06	27
CAD/DM SF	3/7/2006	5/16/2006	10	3/3/2007	5/10/2008	10
ARI QD	7/20/2006	9/14/2006	12	11/1/2006	8/31/2007	12
CAD QD*	N/A	N/A	N/A	3/24/2008	3/31/2009	15

* CAD QD did not have a pilot due to the study time constraints.

Interventions

The interventions consisted of two types: Smart Forms and Quality Dashboards. Smart Forms were customized note-writing templates that were built into the LMR. They gathered and organized existing data relevant to the management of patients with ARI or CAD, allowed for physician entry of additional relevant data, provided decision support tailored to current guidelines and patient information, and allowed for documentation, ordering, and updating of LMR data in a single step. They also facilitated tasks such as printing patient instructions and scheduling follow-up appointments.

Quality Dashboards provided a report of all the patients with CAD or ARI seen by a particular physician regarding adherence to recommended guidelines (e.g., aspirin use for patients with CAD, antibiotic over-prescribing in patients with bronchitis). Graphical displays

allowed for comparisons among physicians within a practice as well as comparisons to local and national benchmarks. Other features facilitated physician actions such as letter writing and test ordering.

Statistical Analysis

All randomized controlled trials data were analyzed on an “intent-to-intervene” basis. That is, any visit occurring in a clinic assigned to Smart Forms or Smart Forms plus Quality Dashboards, whether the physician did or did not use either intervention, was considered an intervention visit in the analysis. We assessed the significance of the Smart Forms or Smart Forms plus Quality Dashboards on the primary outcomes, as appropriate for each condition. A patient in the study clinics could be a subject in the ARI study, the CAD study, both, or neither, depending on whether he/she fulfilled the inclusion criteria for that particular visit. For CAD analyses, the patient was the unit of analysis because we looked into whether the patient met guidelines at the end of the study period, regardless of the number of visits. For ARI analyses, the unit of analysis was the visit because the important question was whether an antibiotic was prescribed at a given visit. Other than its effect on correlation (see below), this difference did not affect the analytic approach.

For dichotomous outcomes (e.g., prescription of aspirin for CAD, antibiotic use in ARI), the outcomes were measured and analyzed on a per patient basis, although conceptually it is simpler to think about the percentage of patients in each group who met the guidelines at the end of the study period. For the three-armed trial, there were two primary comparisons: guideline compliance in each intervention group compared to the control group. Because of the multiple testing issues a Bonferroni adjustment was used to determine significance, so that a p value < 0.025 was required for each of the two tests of efficacy. The comparison of the two intervention arms to each other occurred as a secondary outcome.

Univariable analyses of the primary predictor (i.e., intervention group) were performed for the primary outcomes (adherence with each guideline, each of which is a dichotomous variable) using Chi-square or Fisher’s Exact tests in order to get a general sense of the data. Univariable analysis was also performed on potential confounders using standard statistical tests (Chi square or Fisher’s exact test for dichotomous or categorical variables, chi-square test for trend for ordinal variables, Student’s t-test or Wilcoxon rank sum for continuous variables, depending on the normality of the data). Univariable statistical methods were also used to describe the patient population in each treatment arm in terms of demographics and clinical characteristics.

We then built multivariable logistic regression models, with the primary outcome being guideline adherence at the end of the study period. The assigned intervention group was a primary predictor. We built a model adjusting for guideline adherence immediately before the study period and all potential confounders were identified through a significance level of $p < 0.10$ from univariable analyses. Potential confounders included patient factors (age, gender, race, median income by zip code, insurance type), physician factors (age, gender, and patient volume), practice factors (size of practice), and predictors unique to each outcome (e.g., number of years since diagnosis of CAD (for all CAD outcomes), signs and symptoms associated with antibiotic prescribing (for ARI outcomes)). Any potential confounders that changed the effect estimates for the intervention covariates by more than 10% were retained as part of the final model.

Multivariable models took the following general form, with the dichotomous variable “intervention” (Smart Form vs. Control; Smart Form plus Quality Dashboard vs. Control) as the independent variable of interest:

Outcome = intervention + patient variables + physician variables + clinical variables

In addition, our CAD analyses took into account a design feature that while the patient is the unit of analysis, the practice site is the unit of randomization and the physician is the main target of the interventions. To adjust for clustering of patients within physicians and physicians within practice sites, we used two-level hierarchical regression models to account for intra-class correlations. For ARI analyses, there are actually three levels of correlation (visits within patients within physicians within practices), so we used three-level hierarchical models. The SUDAAN program was used to carry out the modeling, incorporating an exchangeable correlation structure within patient, physician, and practice site.

For the secondary outcomes, we performed similar univariate and multivariable analyses, using similar statistical techniques as for the primary outcomes. For continuous variables (e.g., LDL cholesterol, blood pressure in CAD), multivariable analyses was performed using linear regression in a similar model-building strategy to that described above for logistic regression. For cost data (e.g., antibiotic costs in ARI), if the distribution of costs is not normally distributed, we used either a t-test with log transformation of cost or Wilcoxon rank sum in univariable analyses.

To preserve statistical power and reduce the costs of the study, we decided not to include a separate “quality dashboard only” arm. We also view the quality dashboard as a complement to smart form documentation, and not necessarily as a stand-alone intervention. As a rough estimate of quality dashboard’s ability to improve care by itself, we compared each of the main outcomes before and at the end of the pilot period in the practice group that received it.

We used SAS software (SAS Institute, Cary, NC) and SAS-callable SUDAAN statistical software (Research Triangle Institute, Research Triangle Park, NC), which is capable of adjusting for multilevel clustering effects for all analyses.

Evaluation of Outcomes

Outcomes were collected electronically from the Partners Central Data Repository. In addition, in a 10% subset of patients in the ARI cohort, medical records were reviewed to validate diagnoses, signs and symptoms, antibiotic use, test results, and comorbid conditions.

ARI Cohort: Primary Outcome. We evaluated antibiotic prescribing rates.

ARI Cohort: Secondary Outcomes. We evaluated appropriateness of antibiotic prescribing; re-visit rates within 30 days, antibiotic costs, use of broad-spectrum antibiotics, all-cause antibiotic use, rates of different ARI diagnoses, quality of documentation regarding specific ARI signs and symptoms.

CAD Cohort: Primary Outcomes. We evaluated aspirin use (on medication list at end of study period), beta-blocker use, ACE inhibitor use, LDL testing, LDL < 100 mg/dL, blood pressure < 140/90 mm Hg, Hgb A1c testing and Hgb A1c < 7 among diabetics.

CAD Cohort: Secondary Outcomes. We evaluated LDL cholesterol, blood pressure, and Hgb A1c levels as continuous variables; quality of documentation: blood pressure, height, weight, BMI, and smoking status; allergies or intolerance to aspirin, beta-blockers, and ACE inhibitors; family history of CAD; test results from outside laboratories; reasons for non-adherence with guidelines.

Usability Testing

Clinicians sent their comments by email during a 3-month pilot period in which they used the module for the documentation of actual visits. Another set of comments was entered in an online survey at the end of the pilot. We also extracted direct quotes of clinicians from transcripts of interviews and think-aloud study protocols that were completed as parts of usability evaluation. Although collected through a variety of methods all comments were reviewed and analyzed by usability experts. We analyzed all 155 statements about usability problems collected during the study to identify emergent themes following grounded theory principles. Two researchers then independently assigned the statements into heuristic categories, either general or modified according to newly identified themes. Several iterative coding sessions and discussions ensued, and as a result of extensive comparison and refinement, twelve heuristic categories were formulated.

Ensuring Safety of Participants

Study participant safety was assured through our data collection, analysis and monitoring procedures, to preserve patient confidentiality protects their safety. No patients received less than standard of care.

Results

ARI SF Pilot. Ran for 6 weeks and included 16 physicians from within the Partners network (10 Massachusetts General Hospital (MGH) and 6 Brigham and Women's Hospital (BWH)). This group of 10 Partners-affiliated physicians represented 9 different practices in the Partners network. Although nurse practitioners were among those invited to participate in the pilot, all 10 participants who used the ARI Smart Form with real patients were physicians. These clinicians included 5 women, had a mean age of 42 (SD±6.7) years old, and, on average, graduated from medical school 15 years previously. Nine of the pilot clinicians had primary care practices and 1 saw only urgent care patients.

The mean age of the 26 patients for whom the ARI Smart Form was used was 44 (SD±15) years old and included 15 (60%) women. Of these patients, 17 (65%) were white, 2 (8%) were Latino, and 7 (27%) had unknown race and ethnicity. Twenty-four patients (92%) spoke English as their primary language.

Overall, during the pilot period, clinicians prescribed antibiotics to 35% (9 of 26) of patients when using the ARI Smart Form and 38% (15 of 39) of patients when not using the ARI Smart Form for ARI visits. For antibiotic-appropriate diagnoses, clinicians prescribed antibiotics in 6

of 6 visits (100%) when using the ARI Smart Form, 9 of 10 visits (90%) when not using the ARI Smart Form compared to 154 of 367 visits (42%) during the previous cold and influenza season.

Ten pilot clinicians responded to the post-pilot survey. Three clinicians felt the ARI Smart Form was marginally timesaving, 5 felt it was time-neutral, 1 felt it marginally increased work, and 1 felt it significantly increased work. Six out of the ten clinicians would recommend that other clinicians use the ARI Smart Form unmodified and 3 would recommend it with some minor modification, such as increasing flexibility with more “freelance choices” and making the final note “flow more naturally.”

ARI SF RCT. Ran from November 3, 2005 to May 31, 2006, during which period patients made 21,961 ARI visits to study clinics. This study yielded results on antibiotic prescribing rates as well as ARI guidelines familiarity. In the intent-to-intervene analysis, clinicians prescribed antibiotics to 43% of patients with ARI diagnoses in control clinics and to 39% of patients with ARI diagnoses in intervention clinics (odds ratio [OR], 0.8; 95% confidence interval [CI], 0.6 to 1.2; $p = .30$). There was no significant difference in antibiotic prescribing for antibiotic-appropriate ARIs (OR, 0.8; 95% CI, 0.5 to 1.3) or for non-antibiotic appropriate ARIs (OR, 0.9; 95% CI, 0.6 to 1.4). There was also no significant difference in antibiotic prescribing between control and intervention clinics for non-ARI Visits (5% in control clinics versus 6% in intervention clinics; OR, 1.1; 95% CI, 0.9 to 1.3) or for all visits (9% in both control and intervention clinics; OR, 1.0; 95% CI, 0.8 to 1.2). In the as-used analysis, for visits in which the ARI Smart Form was used ($n = 990$), there was good agreement between the ICD-9 diagnosis and the Smart Form-listed diagnosis (κ , 0.54; 95% CI, 0.50 to 0.58). In the as-used analysis with diagnoses derived from the ARI Smart Form, antibiotic prescribing rates were 88% for antibiotic appropriate diagnoses (compared with 59% in control visits; OR, 5.0; 95% CI, 2.9 to 8.6), 27% for non-antibiotic appropriate diagnoses (compared with 34%; OR, 0.7; 95% CI, 0.5 to 1.0), and 49% for all ARI diagnoses (compared with 43%; OR, 1.3; 95% CI, 0.8 to 2.0). In the as-used analysis, the antibiotic prescribing rate was lower for acute bronchitis (45% vs. 61%, OR, 0.5 compared to control clinics; 95% CI, 0.3 to 0.8). Please, refer to Table 2 for a summary of study results.

ARI SF Usage. In 27 PHS affiliated intervention clinics, 33% (86/262) of clinicians used the ARI Smart Form at least once. Based on ICD-9 codes, the ARI Smart Form was used in 6% (742/11,954) of ARI Visits. For intervention ARI visits at which the ARI Smart Form was used, the duration of ARI Smart Form use was 8.1 (standard deviation, 5.8) minutes.

ARI QD RCT was completed August 31, 2007. Data has been retrieved from the Partners Central Data Repository and data analysis is nearly complete.

CAD/DM SF Pilot. Ran from 3/7/2006 to 5/16/2006 and involved 30 clinicians. For this pilot all SF users went through SF in-person training sessions (from 3/07/2006 to 3/31/06). For those users who could not attend, we made an online “Robodemo” instruction tutorial available. The majority of the participants were primary care physicians (77%) but also included specialists (4 endocrinologists and one cardiologist), and nurse practitioners (2). Most participants were attending physicians, with a mean of 20 years since graduation from medical school. Clinicians saw an average of 27 patients per week; this number reflects the high number of clinicians in the Partners system who practice part-time. As expected, self-reported experience with using the LMR varied, with 23% very experienced and 20% somewhat or very inexperienced.

Approximately one quarter of clinicians usually or always wrote their visit notes in the LMR during the patient visit.

During the pre-intervention and intervention periods, clinicians saw 1940 patients with CAD and/or DM. Patients were 51% women and had a mean age of 65 years; 79% of the patients had DM, 35% had CAD, and 14% had both. Compared with patients during the intervention period for whom the Smart Form was not used, those patients for whom the Smart Form was used were more likely to have a managed care insurance plan, less likely to have Medicare, less likely to have CAD, more likely to have DM, and had fewer medical problems documented in the LMR Problem List.

During the intervention period, 21 participants (70%) used the CAD/DM Smart Form at least once. Seventeen participants (57%) used the Smart Form with two or more patients, and two participants opened the Smart Form during ten or more patient visits during the 6-8-week period. During the intervention period, the Smart Form was used with 150 patients, while there were 935 visits by patients with CAD or DM during the intervention period in which the Smart Form was not used (i.e., the Smart Form was used in approximately 14% of eligible visits).

Sixty-one percent of participants completed the pre-pilot survey and 48% completed the post-pilot survey. Survey responses suggested a trend towards improved participants' satisfaction with their management of smoking, ACE I/ARB use, and especially diet and exercise, but these differences were not statistically significant. In the post-pilot usability survey, the majority of participants agreed that the CAD/DM Smart Form helped them to improve compliance with clinical guidelines and improve the quality of patient care. Survey results also showed that pilot participants do not currently consider the CAD/DM Smart Form to be a timesaver or a tool to improve their workflow. Users reported the following Smart Form features as most helpful: organizing data, providing assessments for each area of disease management, providing suggested orders based on individual patient data, and printing patient instructions.

Pre-RCT Online Survey. For both ARI and CAD/DM Smart Form, survey was distributed to 976 clinicians in order to address the secondary goal of evaluating clinical guideline adherence. This survey was used to ascertain clinicians' demographics, workflow, typical use of the Longitudinal Medical Record (LMR, an electronic health record used at Partners institutions), and opinions regarding decision support tools available in the LMR. The survey was with 257 clinicians responding (response rate - 45%).

CAD/DM SF RCT. Ran for 310 days (March 3, 2007 to May 10, 2008; it encompassed 10 PHS Primary Care Practices with 239 physicians and 7009 patients. Data was collected from over 26,000 visits. All data has been retrieved from the Partners Central Data Repository and preliminary analysis completed. Although more extensive analysis is being conducted presently, preliminary results indicate that patients of CAD/DM Smart Form users were more likely to have deficiencies in care addressed. The analysis showed up to date patient BP result in 32% of patients in the intervention group compared to 24% in the control group ($p < 0.001$), up to date height/weight result in 5% of patients in the intervention group compared to 4% in the control group ($p < 0.001$). Overall percentage of deficiencies addressed in the intervention group was 11.4% compared to 10.1% in the control group ($p < 0.001$). Even when the Smart Form was not used, performance in the non-intervention group (using existing CDS tool, EOVS) was slightly better than in control group. An up to date patient BP result was shown in 30% of non-intervention group patients compared to 24% of control group patients ($p < 0.001$). This result

may indicate an influence of Smart Form on PCP awareness and awaits further analysis. Results are summarized in Tables 3-5.

CAD/DM Post-RCT Survey. Showed a response rate of 36% (N=57). Seventy percent of the respondents (N=40) to the survey used the SF on a regular basis, and were thus able to provide answers to all questions on the survey. Of the regular users, 82% agreed with the recommendations the SF provided, 64% agreed that SF helped them comply better with CAD/DM guidelines, while 47% believed SF changed what they normally would have done for their patients' blood pressure, cholesterol, or glycemic control. In addition, more than half of the respondents found features in the CAD/DM SF that facilitated patient education to be useful: 66% of respondents found the patient instruction handout feature to be helpful and 56% found the "Patient View" feature helpful (See CAD/DM Smart Form screenshots, Figure 2a-b).

CAD QD RCT. Ran from March 24, 2008 to March 31, 2009 and encompassed 15 ambulatory primary care practices. A post-RCT survey was distributed to 76 providers. Relevant results are presented in Table 6 and Figure 1.

SF Usability Testing. Was performed concurrently with CAD/DM pilot testing. Two scenarios for standardized patients were used in the usability testing to compare physicians typical way of documenting a visit; one documenting with the SF during a visit and one documenting after a visit. There were 155 comments from 36 clinicians obtained either in the form of written communication (email and survey) or transcribed from direct verbal quotes (interview and evaluation). We received 85 emails from nine clinicians (reflecting a 50% response rate), and 20 free-text comments were entered in the online survey by 15 clinicians (54% response). Six clinicians who participated in usability evaluations made 26 comments and another six clinicians made 24 distinct comments during interviews. Over a half of all responses (55%) were emails, and about equal numbers were obtained from the survey, evaluations and interviews (15%, 13% and 17%, respectively). The most common form of a response that constituted about a third of collected data (N=54) was an email classified as either a Biomedical, Control or Fault category.

Comments from other survey sources were most likely to be classified in the following categories: Customization and Control for survey (N=9, 45%), Transparency and Workflow for evaluations (N=14, 54%), and Cognition and Workflow for interviews (N=13, 54%). Overall, the Control, Cognition and Biomedical categories described about a half of all data (52%), and about a third (35%) was classified in the Customization, Workflow and Technical categories. There were no Consistency or Context comments.

There were 47 findings extracted from expert reports. Over two thirds were classified into just three categories: Cognition, Customization and Workflow. In contrast, none were in the Fault, Speed or Terminology categories and only one was classified as Biomedical. Technical and biomedical concepts were generally not represented in the evaluations. We contrasted all 47 findings with a subset of 105 comments that included only email and survey. Findings were derived from reports of evaluation and interviews that already contained reinterpreted verbal comments of the subjects. We therefore excluded comments made during evaluations from the comparison.

The Smart Form represents documentation-based clinical decision support that goes beyond standard interruptive methods by dynamically rendering an integrated data review, clinical documentation, and decision support environment for the end-user. Critical to the success of this

application's development (and critical lessons for EMR developers and vendors) were strong participatory design principles, iterative development, and an understanding of clinician workflow and psychology. By integrating decision support into a clinician's workflow, the Smart Form has the potential to facilitate documentation of coded, actionable data, improve the quality of decision-making, and improve the management of patients with acute and chronic medical conditions.

Continued Work

In the course of this project we have developed two novel tools for integrated documentation-based decision support – Smart Form and Quality Dashboard. We have implemented these systems at ambulatory primary care settings and evaluated their usage and impact on clinicians' workflow. For the purpose of this study we focused on three clinical areas – ARI, CAD and DM.

As described above, four RCT studies were conducted in the duration of this five-year project. Complete data sets were retrieved and are presently being analyzed by the project team.

There is a certain trend emerging from the study results up to this point even though the data analysis is still ongoing. Overall, use of Smart Forms and Quality Dashboards as a part of clinical decision support correlates with better adherence to the clinical guidelines within the clinical areas described. Also, most users found these tools intuitive to use, easily integrated into clinicians' workflow and beneficial in terms of quality of patient care.

Looking forward, these are our plans for the next 6-12 months:

1. Completion of data analysis of ARI quality dashboard as a reporting tool
2. Completion of data analysis CAD quality dashboard as a reporting tool
3. Evaluation usage and usability of the QD application
4. Identification of potential barriers to use of the quality dashboard in clinical decision support
5. 9 manuscripts are being worked on by the leading investigators of our group to be submitted for publication in peer-reviewed journals.

List of Publications and Products

Journal Publications

1. Linder JA, Rose AF, Palchuk MB, et al. Decision support for acute problems: the role of the standardized patient in usability testing. *J Biomed Inform.* 2006 Dec;39(6):648-55.
2. Schnipper JL, Linder JA, Palchuk MB, et al. "Smart Forms" in an Electronic Medical Record: Documentation-Based Clinical Decision Support to Improve Disease Management. *J Am Med Inform Assoc.* 2008 Jul-Aug; 15(4):513-23.
3. Linder JA, Rigotti NA, Schneider LI, et al. An Electronic Health Record-based Intervention to Improve Tobacco Treatment in Primary Care: A Cluster Randomized Controlled Trial. *Arch Intern Med.* 2009 Apr 27; 169(8):781-7.
4. Linder JA, Schnipper JL, Tsurikova R, et al. Documentation-based clinical decision support to improve antibiotic prescribing for acute respiratory infections in primary care: a cluster randomized controlled trial. *Inform Prim Care* 2010; in press.

Posters and Conference Presentations

1. Linder JA, et al. Improving Workflow and Quality for Acute Respiratory Infections with an electronic 'Smart Form'. SGIM 29th Annual Meeting; 2006 Apr 26-29; Los Angeles, CA.
2. Linder JA, et al. Barriers to Electronic Health Record Use during Patient Visits [poster]. *AMIA Annu Symp Proc*; 2006 June 4-7; Washington, DC; 2006:499-503.
3. Linder JA, Schnipper JL, Tsurikova R, et al. Barriers to Electronic Health Record Use during Patient Visits. American Medical Informatics Association Annual Conference; 2006 Nov 11-16; Washington, DC.
4. Schnipper JL, Linder JA, et al. CAD/DM and ARI Smart Forms [abstract]. *AHRQ "Work in Progress" session*; 2006 Sep 14;
5. Melnikas AJ, Linder JA, Schnipper JL, et al. Can a "Smart Form" Increase Physicians' Satisfaction with Managing Patient Health Behavior Risks? Results of a Physician Satisfaction Survey [poster]. SGIM Annual Conference; 2007 April 25-28; Toronto, ON, Canada.
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