Grant Final Report

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Rural Trial of Clinic Order Entry with Decision Support

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Abstract

None provided.

Final Report

Purpose

Implement New Health Information Technology in Primary Care Clinics

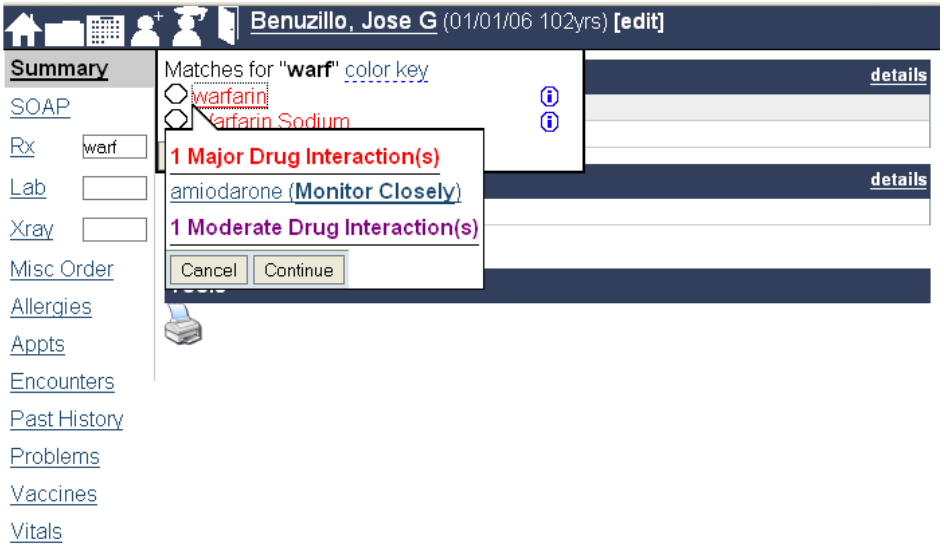
Overview. We implemented and evaluated the computerized clinic order entry (CCOE) tool, a Web-based program for generating and executing ambulatory orders. We performed a cluster randomized trial in rural primary care clinics. Our technology partner in this study was CaduRx. The acronym used for this study was INFORM (Intelligent Network for Registries and Order Management)**.**

The primary order entry features of the CCOE tool included a prescription writer and laboratory and x-ray order entry modules. It was designed for use with handheld computers, but works as well on a tablet or desktop computer. The program was designed primarily for safety, ease of use, and capacity to integrate decision-support. Features included on-the-fly drug to drug interaction prompts, automatic allergy and drug intolerance checking, ICD9 coding for lab and x-ray orders including sensitivity to Medicare coding rules, capacity to drill-down to the Multum™ database for detailed prescribing recommendation, the ability to print orders, fax them directly to pharmacy, lab, or x-ray department, and direct electronic transmission to participating pharmacies. Computer logic generates adult vaccination reminders and provides individualized recommendations for antimicrobial therapy. Ordering histories are visible to all physicians using the system (who have a medical relationship with the patient), including a history of refusals to fill a requested controlled substance. The prescription writer can generate a refill queue to facilitate hand-off from nursing staff to the primary care provider. Although it is possible to create orders for custom formulations or usage instructions for drugs, generally the order writer forces the user to use medications and doses which are actually in use according to the Multum™ formulary. For the sake of user convenience and speed of prescribing, it defaults to the most often-used schedule for repeatedly prescribed drugs and supports an easily accessible list of personal favorites with fixed schedules and quantities. This enables the program to become faster and more accurate as the physicians use it over time. Using the tool, a complete prescription written for the first time can be written in about the same amount of time as writing a paper prescription. However, refills and favorites can be produced in 3-5 seconds including telephone refill requests on the queue.

Drug-Drug Interaction Checker. The drug-drug interaction checker displayed information about potential drug-drug interactions above the electronic prescription pad (Figure 1). Drug names color coded red indicated a major drug-drug interaction, purple indicated a moderate reaction, and green indicated the drug is not known to have a moderate or severe interaction with any of the patient's active medications - minor reactions were not targeted. When an order was attempted with a medication identified as having a major drug interaction the alert presents in a separate window and the prescriber was forced to hit continue before the electronic prescription

pad appears. Moderate alerts were passive in that the prescriber was allowed to proceed directly to the electronic order view without the extra step required for major alerts.

Figure 1. The interaction checker noted potential drug-drug interactions above the prescription pad



Decision Support Tool for Antimicrobial Prescribing. The respiratory infection algorithm was an individual patient, point-of-care-based clinical decision support tool designed to help clinicians manage patients with acute respiratory infections. The branching logic used in the decision support tool was similar to the algorithm we had implemented in an earlier study in rural communities. At the start of the algorithm, the provider selected one of four options: "upper respiratory tract infection", "lower respiratory tract infection", "other infection", or "not for an infection". If either of the first two options was selected, additional checkboxes were revealed to solicit sufficient clinical information to generate a management recommendation. Information previously entered about the patient such as age, allergies, and weight was integrated into the algorithm.

The program had several different entry points: 1) automated trigger when an antibiotic is chosen during the electronic prescription writing process; 2) initiation from use of the clinic chief complaint; 3) user-directed algorithm button on the patient home page. The algorithm was intended to be easy to use and time-neutral.

Vaccine Reminder. The vaccine reminder was an automated notification to inform the provider when influenza vaccination was indicated on the basis of time of year and patient criteria. CDC recommendations for influenza vaccination were translated into computer logic, driven by the available electronic data about the patient. Chronic diseases such as diabetes mellitus were inferred from the patient's active medication list or from ICD9 codes linked to laboratory test orders. When the reminder popped up or was selected, the provider had the option of declining or canceling or ordering the vaccine the patient. The reason for not vaccinating, such as allergy or already received, was solicited when the vaccine was declined. Choosing to give

the vaccine included an option to print an immunization consent form to be placed in the chart. The vaccine administration date was stored in the patient's electronic record.

Scope

Enrollment of Study Clinics

The study team visited eligible rural primary clinics in Utah, Wyoming, and Idaho between December, 2004 and February, 2005 to solicit participation in the project. Twenty clinics were initially recruited, of which 10 were randomized to early implementation (group A) and 10 to deferred implementation (group B). The CCOE tool was launched in group A clinics between May and August, 2005 and in group B clinics between May and August, 2006. One group A clinic declined to proceed to the launch phase of the study and withdrew from participation. During the course of the first study year, three clinics in group B elected to purchase an alternative electronic medical record and dropped out of the study. Two additional rural clinics from among the originally-defined pool of eligible clinics were recruited as replacements. However, two of the clinics in group B withdrew from the study within 2 months after launching use of the CCOE tool. Reasons for study withdrawal were relocation of the clinic physicians to another state in one instance and closure of the clinic practice in the other instance. Thus, a total of sixteen clinics completed the study and were evaluable, nine from group A and seven from group B.

A second randomization was performed in September, 2006, after the group B clinics had begun use of the CCOE tool. The second randomization was used to determine which clinics to assign to use of the embedded respiratory infection algorithm during the winter respiratory infection season 2006-2007. Two of the 16 study clinics were removed from participation in the second randomization because they had participated in a previous study of antimicrobial decision support. Of the 14 remaining clinics, 7 were randomized to use the CCOE tool *with* the respiratory infection algorithm and 7 were randomized to continue to use the CCOE tool *without* the respiratory infection algorithm. Each algorithm arm contained four group A clinics and three group B clinics. A clinic randomized to use the respiratory infection algorithm refused algorithm implementation and was removed from the analysis of the effect of the algorithm on antimicrobial prescribing.

Implementation Strategies and Procedures

CCOE Tool Launch. The process of launching the CCOE tool was divided into three stages: pre-launch, launch, and post-launch. The activities of the pre-launch phase included: a) installation of a high-speed wireless internet system, with a minimum of 128-bit WEP encryption and with accessibility in all patient care areas; b) downloading of patient demographic data from the clinic's patient management system and uploading of the data into the CaduRx system; c) preparation of user identifications and security matrix cards; d) completion of required documentation materials, including informed consent and business agreements, with appropriate

signatures; e) collection of data about individual clinicians, provider productivity, and office efficiency. Direct observations were made of clinic work processes, including prescription refills.

The launch phase was kicked off during a two-hour training session with the providers and office staff. At this session, the physicians were given internet-capable handheld computers to use whereas office personnel were trained primarily on desktop computers. The physician training emphasized electronic prescribing and laboratory orders. Training of office personnel underscored use of the scheduler, the refill request queue, and maintenance of the patient database. Dr. Samore and Dr. Bateman, the lead physician investigators, headed the training of physician users. Clinic office staff were trained by the INFORM study coordinators. A short slide presentation was delivered at the training sessions and written guides were distributed. Hands-on use of the tool by clinic personnel began while the INFORM team was on site to allow initial troubleshooting. The clinic staff were given a 24/7 phone number to call for questions and technical support. During the post-launch phase, the INFORM team maintained close follow-up with each clinic to answer questions and troubleshoot problems. Research coordinators contacted key clinic contacts three to five times per week during the initial post-launch period, to ensure successful use of the computerized clinic order entry tool.

Support requirements during follow-up were substantial. In-person visits were performed regularly during the course of the project. Research personnel made approximately 226 field visits to the rural clinics. The rural clinics were highly dispersed; the distance from the northernmost clinic to the southernmost clinic was 550 miles. The estimated cumulative distance traveled during the field visits exceeded 25,000 miles.

The research staff spent considerable time in the clinics, first helping install the wireless networks, then training the providers and staff on the use of the CCOE tool, and finally providing recurring training and troubleshooting technical problems. Other research activities, such as data collection, occurred in the clinics. This type of exposure to the clinic staff and atmosphere allowed the research staff to develop a close relationship with all levels of clinic staff and helped them gain in-depth knowledge of the challenges a primary care clinic faces when trying to implement a new form of Health Information Technology. This knowledge was gleaned from many informal conversations and interactions with various clinic personnel, and was invaluable in the process of implementing and disseminating the CCOE system across the study clinics.

We created graphical reports in Microsoft Access and SAS to prospectively monitor the daily volume of electronic prescribing by individual providers. The tracking system relied on the data warehouse maintained by CaduRx. The number of electronic prescriptions submitted by each provider was plotted against time. Trends and anomalous usage patterns helped to alert our research staff of potential problems. A database was maintained of phone calls and visits with clinics.

A number of technical issues arose. In several clinics, there were problems with the wireless systems that adversely impacted reliability. Adjustments, sometimes requiring identification of new Internet service providers, were systematically executed to resolve these difficulties. In response to user feedback, the computerized clinic order entry tool was progressively refined to add features, improve its speed, and enhance its usefulness. The Tungsten C was the original handheld computer used by our participating clinics, but this product line was discontinued by the manufacturer. After an extensive evaluation of other suitable handheld computers, we switched the Nokia 770 handheld computer.

Vaccine Reminders. The vaccine reminder was activated in group A clinics between October 11, 2005 and February 2, 2006 and in group B clinics the between October 27, 2006 until and January 21, 2007. In group A clinics, the reminder was implemented as a pop-up requiring a response from the user before any other action could be taken. The majority of group A providers found the reminder to be annoying and not useful because it typically popped-up at a time when the patient was not available to be immunized. Because of these problems, in group B clinics, the reminder was implemented as a passive flag at the top of the screen. We actively engaged office staff personnel in the launch of the vaccine reminder, particularly in group B clinics. A kick-off meeting was held and a pamphlet describing the operation of the vaccine reminders was distributed. Follow-up phone calls were made to address questions and issues.

Respiratory Algorithms. The respiratory infection algorithms were rolled out at the beginning of the 2006-2007 respiratory virus infection season. Providers in each of the clinics randomized to use the algorithms were asked to participate in a kick-off meeting led by one of the physician members of the INFORM team. We used the meeting to highlight the problem of antimicrobial resistance and to present the rationale for prudent use of antimicrobial drugs. The algorithm was demonstrated and the providers were then trained in its use. Each provider was asked to use the algorithms for a minimum of 100 patients with acute respiratory infection. Ordering an antibiotic opened the algorithm page up automatically.

Methods and Results

Formative Evaluation: Adoption and User Experience

Ambulatory Orders. Altogether, 455,120 electronic prescriptions were written by providers in the 16 study clinics during the 27 month follow-up period. A total of 57 providers used the CCOE tool for at least 3 months. Variation in usage patterns, frequency of use, and mode of use across providers and clinics was substantial. Total numbers of electronic prescriptions submitted by the 57 providers ranged between 133 and 39,574, corresponding to an average number per provider per day (on days of use) between 2.1 and 60.4. Most providers demonstrated a stable pattern of electronic prescription writing following the launch period. Clinicians who were heavy users early on tended to remain heavy users and clinicians who were initially infrequent users tended to remain infrequent users.

Two clinics, one in group A and the other in group B, demonstrated very low CCOE usage rates during the entire course of the project (mean number of electronic prescriptions per month for the entire clinic of less than 60). The other 14 clinics averaged at least 300 electronic prescriptions per month (range: 310 – 2,762). Rates of electronic prescribing were higher among providers in group A clinics than among clinicians in the group B clinics. The mean number of electronic prescriptions per provider per day equaled 17 for group A providers and 11 for group B providers; the mean number electronic prescriptions per provider per month equaled 358 for group A clinicians and 188 for group B providers). Five of six smaller clinics with a solo MD or DO provider associated with one or more nurse practitioners or physician assistants exhibited high CCOE use; one of these six smaller clinics exhibited very low use. The two pediatric clinics

that participated in the study demonstrated low rates of electronic prescribing. A multi-level regression analysis of provider and clinic factors which predict adoption is in progress.

Many providers exhibited a preference to use a desktop or laptop computer instead of a handheld computer. By project end, 31 of the 57 (55%) providers had migrated to the desktop or laptop computer as the predominant device for prescription writing during clinic visits.

Use of the CCOE tool for laboratory and radiologic test ordering was much lower than for electronic prescribing. Nonetheless, 31 of 57 providers used the laboratory order at least once, and 27 providers used the X-ray order feature at least once. Average laboratory orders per provider per month were 9.2 (1-104) for group A and 13.7 (1-58) for group B; average X-ray orders per provider per month were 5 (1 - 32) for group A and 7.8 (1-27) for group B. Ten providers in group A and 4 providers in group B averaged more than 5 laboratory orders per month and 6 providers in group A and 3 providers in group B averaged more than 5 X-ray orders per month.

Vaccine Reminders. In group A clinics, the reminder was viewed 6,702 times in 3,883 unique patients. The influenza vaccine order form was printed for 383 (10%) patients. The most common alternative responses were: “on hold” (70%); “patient already received vaccine” (10%); “vaccine not indicated” (2%); “vaccine refused” (3%); “patient referred elsewhere” (5%); “administered with clinic-specific form” (3%).

In group B clinics, the reminder was viewed 282 times in 188 unique patients. In 96% of these patients, the order form was either printed or the influenza vaccine was administered with a clinic-specific form.

Respiratory Infection Algorithms. The respiratory infection algorithms were implemented for a 9 month period in six clinics between October, 2006 and June, 2007. Seventeen of 21 providers in the six clinics completed 3 or more algorithms; the median number of completed algorithms per provider was 24 (range: 3 – 151) and the median number of opted out algorithms per provider was 104 (range: 2 – 769). Overall, the 17 providers completed 687 (16%) of 4,228 triggered algorithms. The fraction of algorithms completed was 40% during the first month of implementation and declined to 2% by the last month. Ninety-two percent of algorithms were triggered by initiation of a prescription for an antimicrobial agent. In 74% of instances, the triggering antimicrobial agent was amoxillin. Doxycycline was the next most common triggering antimicrobial agent (5%).

Clinician Survey. The clinician survey was developed using the framework of the technology acceptance model. Perceived usefulness, perceived ease of use, and self-efficacy were among the pre-specified domains. Responses were selected on a 7-point Likert scale. The survey was administered in two waves. The first survey included 34 questions and the second survey 41 questions, of which 28 were the same as in the first survey and 13 were new.

The first wave involved clinicians in group A clinics and was distributed 3 to 4 months after CCOE launch in group A clinics. The second wave involved clinicians in both group A and group B clinics and was administered 3-4 months after CCOE launch in group B clinics.

Twenty-eight providers completed the first survey. Forty-four providers completed the second survey; 23 of these providers had also participated during the first wave. Altogether, 29 group A and 15 group B providers completed the second survey, representing 77% of the providers who used the tool for at least 3 months. The highest ranked features of the CCOE

tool were electronic faxing and security. In the second survey, the mean response to the statement "using the CCOE tool decreases the time it takes to write a REFILL prescription" was 5.9, where 7 denoted "strongly agree". The mean response to a corresponding statement about new prescriptions was 4.25. The mean response to the statement "integrating drug reference and drug interaction look-up (D2D) with prescription writing is useful" was 5.6.

Focus Groups. Focus groups were convened with the clinicians participating in the INFORM project in order to explore the challenges and barrier the providers faced when implementing the CCOE tool into their workflow, A research staff member facilitated the focus groups. A standard set of questions was developed that allowed the facilitator to engage the clinicians in a discussion on their personal experiences as participants in the INFORM project. The facilitating questions were focused on the themes of CCOE implementation, office efficiency and provider productivity after introduction of the CCOE, clinic progress towards implementing an EMR, Decision Support features of the CCOE, Patient safety features of the CCOE, and their overall experience as INFORM project participants. Each theme was explored in greater detail, as facilitated by the group leaders.

The topic of patient safety addressed two separate features of the CCOE tool: 1) the drug-drug interaction checker and 2) the drug information database, supplied by Multum™. The clinicians in the focus groups were very opinionated about the usefulness of these features, and whether they should be part of the CCOE tool. First, the drug-drug interaction checker was a feature of the tool that provided the clinician with a warning when a drug was being prescribed that interacted with a medication the patient was currently taking. These warnings were classified into mild, moderate and major interactions. A major interaction warning required the physician to override the system's warning in order to prescribe that particular medication. The minor and moderate interactions were simply pop-up windows that gave the clinician information on the interaction.

The clinicians in the focus groups agreed that the mild interaction messages were not useful, and often were more of an inconvenience than they were worth. One common complaint was that the checker was too sensitive, and would trigger an alert on very common drug combinations. Most participants said that they began to disregard most, if not all, alerts because they were so fatigued by the noncritical ones.

The other patient safety feature evaluated in the focus groups was the drug information in the CCOE tool, supplied by Multum™. Several focus group clinicians stated that the information was especially useful when they were prescribing a new medication. Despite this positive feedback on this feature, many also stated that when they looked up the drug interaction reported by the CCOE in other sources (i.e., Epocrates, Tarascon), the other sources did not list them as a potentially harmful interaction. Several clinicians admitted that they did not fully trust the information in the CCOE, and they checked it against other sources before using it to make prescribing decisions.

Physician Productivity. Study clinics supplied two types of information to support a ballpark assessment of whether the CCOE tool impacted provider productivity. One approach was to have the clinic manager prospectively record for each provider the daily time in, time out, and number of patient visits during separate two week intervals before and after CCOE implementation. The mean number of minutes of office time per patient was comparable across the two time periods. Our other approach was to construct time series graphs of monthly counts

of office visits per provider. None of the clinics for which provider visit data were available demonstrated downward blips or trends during the launch or post-launch phase of CCOE implementation.

Summary Evaluation: Adoption and User Experience. Different components of the tool were variably accepted and adopted. Components which did not appropriately fit within clinic workflow or were interruptive of existing processes were least favorably perceived. Components which saved time such as the electronic submission of prescription refills were highly rated. Each of the decision support tools—the drug-drug interaction checker; the respiratory infection algorithm; and the vaccine reminder—highlighted these issues.

Quantify Effect of the CCOE Tool on Clinic Processes

Analyses of User Interactions with the CCOE Tool: Overview. We used Web log file analytic methods to examine how users interacted with the CCOE tool and how different users interacted with each other during the prescription process. Each observation in the Web log file corresponded to a specific, time-stamped page view that was created each time a user clicked on a page link. Other fields were clinic, user, type of Web browser and device. Using a random patient identification number generated by CaduRx, it was possible to determine which page-views corresponded to the same patient, while maintaining non-identifiability.

Our analysis of electronic prescribing proceeded by dividing chronologically-ordered rows of data into *patient sessions* and *prescription sequences*. Observations pertaining to a single patient in a single clinic during a single day corresponded to a patient session. A single patient session could encompass multiple users and multiple prescription sequences. A prescription sequence was defined as a set of two or more consecutive page views associated with a single patient and a single user, representing steps in the process of submitting an electronic prescription.

Some prescription sequences ended with a submitted prescription order and some did not. Electronic prescription refills typically began with an “Rx Summary” page-view and new electronic prescriptions typically began with an “Rx Search” page-view. The “Rx submit” page view indicated that the electronic prescription had been completed.

Users were classified into two groups: providers and clinical staff. The “Rx submit” page was always generated by a provider, because the “submit prescription” button was only activated for providers.

A submitted prescription was labeled as *new* if no electronic prescription for the same drug had been previously entered for the patient; otherwise, the submitted prescription was labeled as an *existing refill*. Provider-associated prescription sequences that did not end with the “Rx submit” page presumably represented instances of technical glitches (e.g., system crashes) or intentional cancels (e.g., the provider was looking up information or testing features of the tool). Clinical staff members generated prescription sequences by setting up medication queues for the provider to review and submit. Subsequent prescription sequences generated by the provider during the same patient session were classified as “clinical-staff involved” to reflect the participation of the clinical staff in electronic prescription writing during that patient session. Prescription sequences generated by providers with no previous clinical staff contribution were classified as “provider only”.

Analyses of User Interactions with the CCOE Tool: Sequence Analysis. Two measurements were used to examine the efficiency of the prescription ordering process: (1) the number of steps (or page-views) from the beginning of a prescription sequence to the completion of the order; and (2) the duration of time taken to complete each step, calculated by calculating the intervals between successive time-stamps. Fifteen minute time-out and change of user were used to break sessions into discrete blocks of time to account for inactive time between steps when calculating duration. Therefore duration was calculated as the sum of elapsed time between the beginning and end of blocks of time.

Analyses of User Interactions with the CCOE Tool: Results. The following results are based on an analysis of Web log files collected between June, 2005 and January, 2007. A total of 222,629 electronic prescriptions sequences were identified during the 18-month period between June, 2005 and December, 2006, 27% (59,544) of which were staff-involved. Overall, 37% of prescriptions which were "existing refills" were "clinical staff-involved" whereas 20% of "new" prescriptions were "clinical-staff involved".

The tables below show the median number of steps for "provider-only" versus "clinical staff-involved" prescriptions, divided according to whether they were "new" or an "existing refill". Involvement of the clinical staff reduced the number of steps performed by the provider and the duration of provider time needed to submit the prescription. The overall duration of clinical staff-involved prescriptions was longer than for provider-only prescriptions.

Table 1a. Median of number of steps per completed prescription sequence

Prescription Category	Clinical staff involvement: Yes— Median total steps	Clinical staff involvement: Yes— Provider portion steps	Clinical staff involvement: No: (provider only)— Median steps
Rx New to System	9	3	6
Existing Refill	4	2	3

Table 1b. Median duration of completed prescription sequence (seconds)

Prescription Category	Clinical staff involvement: Yes— Median duration	Clinical staff involvement: Yes— Provider portion duration	Clinical staff involvement: No: (provider only)— Median steps
Rx New to System	67	6	48
Existing Refill	18	5	10

Clinic Observations: Methods. The INFORM research staff observed office practices to analyze the tasks involved in refilling prescriptions and to measure the impact of the CCOE tool on the efficiency of processing prescription refills. Structured observations were performed in each clinic before and after implementation of the CCOE tool. The goal of the observation was to observe each type of task related to prescription renewals occurring in different sections of the clinic office.

We created a custom observation recording tool for use on the Palm TX PDA using Pendragon 5.0 software. The task type, elapsed time to complete the task, the location in the clinic where the task was undertaken, and the individual in the clinic who completed the task were recorded. All observations were time-stamped. Stopwatches, pens, and a printed list of the tasks were used by the observers as supplemental equipment, as needed. The data were automatically exported from Pendragon into Microsoft Access.

Clinic observations were used to construct graphical flow charts to depict tasks, decisions, and personnel involved in the processing of prescription refills within each clinic. These graphical charts were used to qualitatively compare clinic processes before and after implementation of the CCOE tool. Tasks which were routine steps in the processing of a prescription refill were classified as required. A task was classified as batched when individual requests were purposefully grouped together rather than managed as a single action. For instance, in the majority of instances, chart pulling was performed as an individual task whereas chart re-filing was a batch process.

Observed refill tasks prior to implementation of the CCOE tool included the following categories:

- Refill request: receiving request by phone, fax, or in-person
- Chart request: submitting a request for the chart to be pulled
- Chart pulling: locating and pulling patient chart from shelf
- Chart re-filing: returning chart to shelf
- Information look-up: reviewing the chart or looking up medication in reference text
- Information clarification: calling patient or pharmacy
- Relay refill request: communicating the refill request to the provider
- Prescription writing: completing handwritten prescription
- Manual faxing: sending fax to pharmacy
- Medication documentation: recording the medication in the chart
- Special: performing ad hoc tasks related to prescription renewal

Task categories that were observed only post-implementation of the CCOE tool included electronic approval/submission and prescription printing.

Clinic Observations: Results. A mean of 6 hours of observation were made per clinic per year in the study. Six different observers visited the clinics; inter-rater reliability was established during 36 hours of dual observation of the same tasks. The table below depicts the analysis of required and optional tasks for prescription refills before and after implementation of the CCOE tool.

Table 2. Required and optional tasks for prescription refills before and after CCOE tool implementation

Task categories	Pre-CCOE tool: Required steps	Pre-CCOE tool: # refill requests observed	Pre-CCOE tool: Mean time to complete task (seconds)	Post-CCOE tool: Required steps	Post-CCOE tool: # refill requests observed	Post-CCOE tool: Mean time to complete task (seconds)
Refill request	X	32	63	X	129	57
Chart request	X	24	43	X	4	24
Chart pulling	X	77	47	X	61	28
Chart re-filing	X	210	20	X	85	14
Information look-up	X	38	48		11	71
Information clarification		68	64		68	76
Relay request to provider	X	47	32		9	42
Prescription writing	X	72	39		25	36
Manual faxing	X	23	39		23	8
Electronic submission				X	26	15
Prescription printing					1	11
Medication documentation	X	38	36	X	13	27
Special tasks		19	62		32	64
Estimated mean time to process routine refill request			**367**			322

The observed prescription refill tasks reflected the hybrid nature of the use of electronic medical records and paper charts in study clinics after implementation of the CCOE tool. For instance, chart pulling and re-filing routinely occurred even after implementation of the CCOE tool in order to document electronically prescribed medications in the paper chart. In selected instances, charts were also pulled to allow the provider to look up information about the patient prior to refill approval or denial. The CCOE tool had a feature which automated printing of prescription labels to paste into charts for purposes of documentation. However, only one clinic consistently used this feature.

Implementation of the CCOE tool affected roles of clinical staff in the refill process variably across clinics. In several clinics, implementation of the CCOE tool was associated with increased involvement of the front desk staff and a rise in batch processing of refill requests.

Summary Assessment: Effect on Clinical Processes. The CCOE tool was not a full electronic medical record and did not result in a paperless office. However, its implementation did result in redesign of clinical processes for prescribing medications. Work among clinical personnel was redistributed toward greater involvement of front office staff. Communication tasks were made more efficient because steps that involved the relay of information on paper notes were eliminated. Refill requests were more likely to be managed in a batch mode. Provider time spent to write refills was saved.

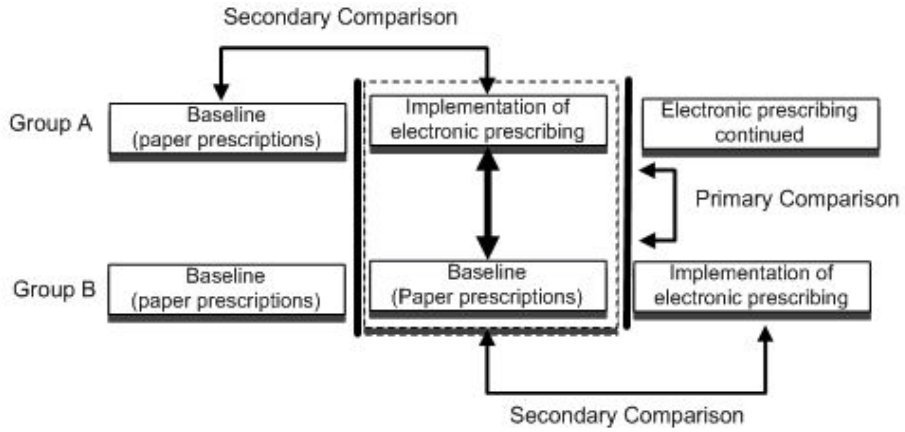
Quantify Impact of the CCOE tool on Clinical Practice

Methods: Chart Review. Paper chart review was the primary means by which we assessed the effect of the CCOE tool on clinical practice. Chart review was necessary because electronic data about medications and other practices were not available from these clinics prior to implementation of the CCOE tool. Three clinical practice domains were studied, linked to the tool's decision support features: medication safety (potential drug-drug interactions); preventive care (adult vaccination); and acute respiratory infection management.

Table 3. Outcome measures defined for each domain

Practice Domain	Primary Endpoints: Type	Primary Endpoints: Definition—Numerator	Primary Endpoints: Definition—Denominator	Primary Endpoints: Comparison—Baseline	Primary Endpoints: Comparison—Intervention
Drug-drug interactions	Rate	# unique potential moderate-to-major drug-drug interactions	Person-drug month	Before CCOE launch	After CCOE launch
Respiratory infection management	Proportion	# clinic visits for upper respiratory infection where antimicrobial agent prescribed	# visits for upper respiratory infection	Respiratory infection algorithm OFF	Respiratory infection algorithm ON
Adult vaccination	Proportion	# adult patients with indication for influenza vaccine who had documented receipt of influenza vaccine	# adult patients with indication for influenza vaccine	Vaccine reminder ON	Vaccine reminder OFF

Figure 2. Clinic groups and intervention periods included in the comparison of drug-drug interaction rates



We developed a chart extraction tool in Microsoft Access using structured data input forms. Documented office visits, medication histories, and immunizations during the interval May, 2004

to August, 2007 were recorded. Medication histories encompassed drug names and dates as listed in the progress notes, with or without an associated office visit. Documented instances of administration of influenza and pneumococcal vaccines within the clinic or outside the clinic were recorded. Office visits were classified as acute upper respiratory tract infection if acute respiratory symptoms were present or if the provider diagnosed an acute upper respiratory infection. The following symptoms associated with acute respiratory infection visits were extracted: cough; congestion; runny nose; fever; sore throat; ear pain.

Reviewers followed an explicit chart review protocol. After entering the medication histories, the chart reviewer activated an automated algorithm to flag potential drug-drug interactions on the basis of prescription dates. The algorithm detected potential interactions involving coumadin, statins, or methylphenidate/adderall. The chart reviewer then indicated whether the hazard was acknowledged or whether any actions were taken to mitigate risk, such as heightened monitoring, modified drug dosage, and initiation of additional drugs (adding a gastroprotective agent when an NSAID was paired with warfarin).

We defined warfarin, lovastatin/simvastatin, and methylphenidate/adderall as object drugs of interest because their high frequency of use and their potential for interaction with a number of other medications (i.e, precipitant drugs).

Table 4. Precipitant drugs and their potential consequences

Object Drug	Precipitant Drug	Anticipated Change in Object Drug's Pharmacologic Effect	Potential consequences
Warfarin	co-trimoxazole, sulfamethoxazole	Increased	Bleeding
Warfarin	Fluconazole	Increased	Bleeding
Warfarin	Amiodarone	Increased	Bleeding
Warfarin	Metronidazole	Increased	Bleeding
Warfarin	Carbamazepine	Reduced	Therapeutic failure
Warfarin	Rifampin	Reduced	Therapeutic failure
Warfarin	NSAIDs	Increased	Bleeding, especially GI
Lovastatin or Simvastatin	Cyclosporine	Increased	Myopathy
Lovastatin or Simvastatin	Gemfibrozil, fenofibrate	Increased	Myopathy
Lovastatin or Simvastatin	Ketoconazole, itraconazole, fluconazole	Increased	Myopathy
Lovastatin or Simvastatin	Erythromycin, clarithromycin, troleandomycin	Increased	Myopathy
Lovastatin or Simvastatin	Amprenavir, indinavir, delavirdine, nelfinavir, ritonavir, saquinavir	Increased	Myopathy
Lovastatin or Simvastatin	Rifampin	Increased	
Lovastatin or Simvastatin	Verapamil, diltiazem	Increased	Myopathy
Lovastatin or Simvastatin	Amiodarone	Increased	Myopathy
Methylphenidate or Adderall	SSRI	Increased	Serotonin syndrome, lowered seizure threshold
Methylphenidate or Adderall	Duloxeting, venlafaxine, bupropion	Increased	Serotonin syndrome, lowered seizure threshold

Another purpose of recording medication histories was to estimate the proportion of prescriptions that were still written on paper after launching the CCOE tool. Each mentioned drug was divided into the following categories: start of a medication new to the patient; refill of a medication previously started by one of the clinic providers; refill of a medication previously started by an outside physician; documented continuation of a medication without indication of a prescription being written; documented discontinuation of a medication. Each prescription was also classified as electronic, paper, or unknown.

The data collection system was iteratively debugged and refined through pilot testing. A procedure manual and data dictionary were developed. Chart reviewers were trained in use of the data collection system. Inter-rater reliability was assessed to ensure consistency. Patient records were reviewed by research staff on the clinic premises.

Two sampling frames were used. The first sampling frame was a random selection of patients conditional on receipt of an electronic prescription for one of the three classes of object drugs in the drug-drug-interaction sub-study. The second sampling frame consisted of randomly sampled patients who had a least one office visit for an upper respiratory tract infection during the study period.

The target enrollment was 75-100 patients from the first sampling frame and 175 patients from the second sampling frame. The random patient identification number associated with the CCOE tool was stored with the reviewed patient record to facilitate linkage with the electronic data warehouse.

Methods: Patient Simulation Exercise. We created a set of scenario-based patient simulation exercises to establish an alternative, experimentally-based approach for assessing impact. The goal of these exercises was to compare efficiency, accuracy, appropriateness, and completeness of medication prescriptions when ordered through the CCOE tool or written by hand. Six types of scenarios for medication management were developed: 1) prescription of a familiar drug; 2) prescription of an unfamiliar drug; 3) prescription at higher dose; 4) prescription for a controlled substance; 5) potential interaction depending on drug selection; 6) prescription refills. Two versions of each scenario with comparable content and difficulty were developed.

A simulated paper patient chart was created for each scenario. The charts contained all of the information that the providers needed to write a prescription, including a problem list, current medications, allergies, correct spelling of patient name, birthday and address. The scenarios were scripted to mimic the types of patients that a provider might see in a primary care practice, with varying ages and conditions. The scenarios were pilot tested with clinicians who were not involved in the project. The research staff member observed the provider execute each scenario task and, using a structured data entry form with a built-in timer, clocked the amount of time taken to complete each prescription.

Providers from each of the study clinics were invited to participate in the simulation exercise. Participants were randomly assigned to either handwrite prescriptions for the first version of each scenario and to use the CCOE tool for the second version of each scenario, or vice versa. Thus, both versions of each scenario were completed for each participant, with the order of the method randomly assigned.

Results: Extraction of Information from the Paper Charts. A mean of 211 patient records were sampled per clinic (range: 125-242). A mean of 70 patients per clinic had

received one or more of the target drugs. The chart review process revealed differences in how the paper charts were organized to support medication management. All clinics had a designated section of the chart that was intended the patient's current medication list. In some clinics the list was updated in the notes with each clinic visit. Other clinics had a paper form at the front of the chart with a column for listing the medications and columns for listing the first time the medication was prescribed, dates of refills and a place for notes (for example, when a drug was discontinued). Adherence to keeping the active medication list up to date or noting when a drug was refilled or discontinued varied across clinics. Most clinics used a combination of tactics (visit notes and the form at the front) with varying degrees of consistency. Copies of prescriptions were sometimes attached inside the chart in place of a written note. Refill requests were recorded in the progress notes or on the medication list, with varying degrees of reliability.

Documentation of immunizations was similarly inconsistent. Some clinics specifically stated that administered vaccines would be recorded in the notes; others had a specific section of the chart where signed consents and documentation of vaccinations were filed and still others had a specific form to record the date and type of vaccine given.

Results: Drug-Drug Interactions. A total of 148 coumadin-associated potential drug-drug interactions (DDI), 43 statin-associated DDI, and 122 methylphenidate/adderal-associated DDI were observed. Rates of drug-drug interactions are displayed in the tables below:

Table 5a. Baseline rates of potential DDI

	Group A clinics pre-CCOE # DDI per 100 person months: Overall rate	Group A clinics pre-CCOE # DDI per 100 person months: Range	Group B clinics pre-CCOE # of DDI per 100 person months: Overall rate	Group B clinics pre-CCOE # of DDI per 100 person months: Range across clinics
Coumadin DDI	5.5	2.3-20.0	16.3	8.7-29.5
Statin DDI	2.4	1.0-12.5	2.6	0.9-12.1
Methylphenidate/Adderal	6.9	3.1-26.7	15.8	11.4-115.0
Combined DDI	4.4	1.0-26.7	11.5	0.9-115.0

Table 5b. Rates of potential DDI after implementation of the CCOE tool

	Group A clinics post-CCOE # DDI per 100 person months: Overall rate	Group A clinics post-CCOE # DDI per 100 person months: Range rate	Group B clinics post-CCOE # of DDI per 100 person months: Overall rate	Group B clinics post-CCOE # of DDI per 100 person months: Range
Coumadin DDI	9.9	5.1-26.5	12.9	1.7-18.6
Statin DDI	2.3	0.8-13.0	5.3	1.7-21.6
Methylphenidate/Adderal	4.5	0.9-16.3	7.4	2.2-69.6
Combined DDI	5.3	0.8-26.5	8.2	1.7-69.6

Table 5c. Rate ratio for potential DDI, post- versus pre- CCOE implementation

	Group A and B clinics combined: Rate ratio calculated as post CCOE/pre CCOE: Rate ratio	Group A and B clinics combined: Rate ratio calculated as post CCOE/pre CCOE: Range rate ratio
Coumadin DDI	1.1	0.4-11.7
Statin DDI	1.4	0.8-2.7
Methylphenidate/Adderal	0.5	0.2-1.9
Combined DDI	0.9	0.8-11.7

On balance, these results suggest that overall rates of potential DDI associated with these three drug classes did not significantly decline following implementation of the CCOE tool. Additional analyses of these results using hierarchical regression models are in progress.

Results: Vaccination. First, we examined documented influenza vaccination rates in 1,270 patients aged 50 years or greater whose records were reviewed. During the baseline season, 4% of patients in group A clinics (range: 1-9%) and 6% (range: 1-9%) of patients in group B clinics were documented to have received influenza vaccine. During implementation of vaccine reminders, the fraction of individuals documented to have received influenza vaccine increased to 7% in group A clinics and 14% in group B clinics. The increase in influenza vaccination was statistically significant ($p<.05$) in a random effects model.

Results: Antimicrobial Prescribing. A total of 2,438 patients with 5,780 URI visits were reviewed. An antibiotic was prescribed in 65% percent of the URI visits. Across individual clinics, the fraction of URI visits prescribed an antibiotic ranged from 51% to 80% prior to implementation of the respiratory algorithms. In clinics from which data were available pre- and post- implementation of the respiratory infection algorithm, the fraction of URI visits prescribed an antibiotic did not decline. We are currently extracting additional records to obtain an adequate sample or patient records in both groups of clinics post implementation of the respiratory infection algorithms.

Results: Patient Simulation Exercise. Twenty-seven providers participated in the patient simulation, representing 1-4 providers from 14 study clinics.

Table 6. Mean time to complete each medication prescription for each scenario

Scenario	Category	Electronic Mean seconds per script (sd)	Handwritten Mean seconds per script (sd)
1	Familiar drug	75.5 (46.5)	44.9 (25.0)
2	Unfamiliar drug	86.0 (67.4)	76.8 (61.2)
3	Change dose	38.0 (22.2)	49.5 (19.6)
4	Controlled substance	73.1 (50.4)	38.5 (13.5)
5	Drug interaction	71.8 (62.7)	38.5 (16.7)
6	Refills	26.2 (16.6)	34.5 (10.1)

Scenario five presented a situation where the provider was asked to choose an antibiotic to treat the simulated patient's infection. The simulated patient's medication list included a drug (e.g., methotrexate for rheumatoid arthritis) that had major interactions with selected antibiotic classes (e.g., TMP/sulfa). Eleven (44%) of 27 providers ordered the interacting drug when handwriting the prescription. In contrast, when using the CCOE tool, only 3 (11%) of 27 providers ordered the interacting drug ($p=.028$).

We are currently comparing rates of medication errors between handwritten and electronic prescriptions.

Summary Assessment: Effect on Clinical Practice. In our initial analyses of data extracted by chart review, we have been unable to detect an effect of the CCOE tool on antimicrobial prescribing or on rate of drug-drug interactions for three classes of medications. An increase in

influenza vaccination was seen despite the low uptake of the vaccine reminder. The major caveat to this finding is that the rates of documented influenza vaccination were quite low both before and after implementation of the reminder. It is likely that a large proportion of patients received influenza vaccination outside the clinic without documentation in the paper chart.

The results of the patient simulation exercise confirmed that using the CCOE tool was time-saving for refills. New prescriptions for familiar drugs and controlled substances took longer with the CCOE tool. Responses to the drug interaction scenario highlight the potential benefit of the drug-drug interaction checker, as described anecdotally by the providers.

List of Publications and Products

Presentations

Pettey W, Benuzillo J, Carter M, Jacketta C, Fjelstad M, Wuthrich-Reggio A, Bateman K, Samore M. Describing the use of an internet-based computerized clinic order entry (CCOE) tool in rural medical practice. Poster presented at: American Public Health Association Annual Conference; November 3-7, 2007; Washington, D.C.

Sauer, B., PhD, Benuzillo, J.G., MS, MA, Pettey, W.B., MPH, Bateman, K., MD, Samore M.H., MD. Evaluation of Drug-Drug Interaction Alerts in a Rural Health Computerized Order Entry System. Poster presented at: Agency for Healthcare Research and Quality 2008 Annual Conference, September 7-10, 2008, Bethesda, MD.

Shen S, Benuzillo J, Pettey W, Jensen J, Wuthrich-Reggio A, Bateman K, Samore M. Analysis of "Web Logs" to Improve Web-Based Clinical Order Entry Systems. Poster presented at: Agency for Healthcare Research and Quality 2007 Annual Conference; September 26, 2007; Bethesda, MD.

Phansalkar S, Wuthrich-Reggio A, Staley R, Morales W, Bateman K, Samore, M. Understanding adoption of the Computerized Clinic Order Entry (CCOE) tool among physicians in rural Utah. Poster presented at: American Medical Informatics Association 2006 Spring Congress.

Samore M, Benuzillo J, Shen S. Analysis of "Web Logs" to Improve Web-Based Clinical Order Entry Systems. Podium presentation at: Agency for Healthcare Research and Quality 2007 Annual Conference; September 26, 2007; Bethesda, MD.

Wuthrich-Reggio, A. The INFORM project: implementing health information technology in rural primary care clinics. Invited oral presentation: Seventeenth Annual Meeting of the Utah Rural Health Association; October 2005; Cedar City, UT.

Manuscripts Submitted

Usage Mining of Electronic Prescribing Log files to Identify and Evaluate Improvements in Provider-Staff Medication Ordering Patterns Shen S, et al

Rural Physicians' Experience with Computer Drug-Drug Interaction Alerts Benuzillo J., et al.

Manuscripts in Preparation

Impact of Drug Interaction Alerts on Rates of Potential Drug Interactions Sauer B, et. al.

Adoption of Computerized Order Entry in Rural Primary Care Clinics Phansalkar S., et al.

Randomized trial of Clinical Decision Support for Respiratory Infection Management in Rural Primary Care Clinics Samore M, et al.