Grant Final Report

Grant ID: 5R18HS017167

Evaluation of a Computerized Clinical Decision Support System and EHR-Linked Registry to Improve the Management of Hypertension in a Community Health Center

Inclusive dates: 09/29/07 - 06/30/11

Principal Investigator:
Helene Kopal, MPA, MPH

Team Members:
Asaf Cohen, MD[*]
Lindsay Farrell, MBA[*]
Pam Ferrari[*]
Donna Goldbloom[*]
Mari Millery, PHD[†]
Donna Shelley, MD, MPH[‡]
Daren Wu, MD[*]

[*] Open Door Family Medical Center, Inc.
[†] Columbia University, Mailman School of Public Health
[‡] New York School of Nursing and Dentistry

Performing Organization:
Primary Care Development Corporation, Inc.

Project Officer:
Erin Grace

Submitted to:
The Agency for Healthcare Research and Quality (AHRQ)
U.S. Department of Health and Human Services
540 Gaither Road
Rockville, MD 20850
www.ahrq.gov

Abstract

Purpose: The purpose of this study was to test the effectiveness of electronic decision support and provider performance feedback in improving the control of hypertension.

Scope: The study evaluates the effectiveness of clinical decision support and provider feedback in the management of hypertension in a community health center, and the factors that impact provider acceptance of health information technology.

Methods: A pre- and post-intervention comparison on blood pressure outcomes and clinical process measures was conducted; we evaluated changes in BP control using an ANOVA test for significance of the BP trends over the 36 month study period. Additionally, we conducted pre- and post-intervention surveys and structured interviews of providers.

Results: Hypertension control was significantly greater post-intervention compared with the baseline period (50.9% vs 60.8% $p<.001$). Process measures also improved significantly. Logistic regression with generalized estimating equations showed that patients were 1.5 times more likely to have BP controlled post-intervention than pre-intervention. Participants found different components useful but manifested more aggressive treatment, and increased attention to hypertension. Facilitators of success included: leadership, organizational culture, provider engagement, rigorous implementation process, framing of intervention as quality improvement, and health center capacity to process data.

Key Words: Hypertension, Quality Improvement, Clinical Decision Support, Implementation

Final Report

Purpose

In accordance with the Funding Announcement's[1] focus on strategies to improve delivery of evidence to the point of care with the goal of improving clinical decision-making and clinical quality for priority conditions, this study analyzed the effects of a multi-component, technology-driven quality improvement intervention on hypertension control. Focusing on low-income immigrant populations, we hypothesized that computerized decision support and provider performance feedback would be more effective for improving hypertension control than a usual, standard care electronic health record. We focused on the use of health information technology (health IT) for guideline implementation to address hypertension, and identified two study aims:

Aim # 1. To test the hypothesis that an office-based electronic health record with decision support and registry-linked provider performance feedback will be more effective in improving hypertension control than a standard electronic health record alone.

Aim # 2. To assess the implementation process and delineate factors that influence adoption of the EHR-supported quality improvement intervention.

Scope

Background & Context

Hypertension (HTN) is the most prevalent modifiable risk factor for cardiovascular disease among US adults and it is among the most common reasons for an outpatient medical visit.[2] Despite the availability of effective medications and published guidelines for the treatment of hypertension, half of US adults who have been diagnosed with hypertension have poorly controlled blood pressure (BP).[3] Several recent literature reviews support a variety of implementation strategies aimed at increasing provider adherence to guideline recommended care processes including clinical reminder systems, and performance feedback.[4,5,6,7,8,9,10] Numerous studies have also examined the efficacy of clinical decision support systems (CDSS) in improving the quality of preventive care.[8,11,12,13] But despite the theoretical and intuitive benefits of such technologies, the existing literature has demonstrated mixed empirical results.[10-12] Moreover, few studies have examined the deployment of CDSS to improve the quality of HTN management,[7,13,14,15] and we are aware of only one study of CDSS conducted in community health centers (CHCs).[16] With primary care practices, including CHCs, responding to federal Meaningful Use requirements to adopt health IT by 2014 there is a need for greater understanding of technology driven quality improvement strategies.[17]

Setting

The study was conducted in a four-site Federally Qualified Community Health Center (CHC), Open Door Family Medical Center (Open Door), located in New York. Open Door installed eClinicalWorks (eCW), an EHR and practice management system, in all four sites in May 2007. The health centers provide primary care to approximately 40,000 patients annually; its population is primarily Hispanic (73.5%) with 60% foreign born. Thirty five percent of patients have Medicaid and 58% are uninsured. More than half (51%) of the patients have a linguistic barrier. Almost three-quarters (73%) of Open Door's patients are at less than 100% poverty and nearly all patients (95%) were at less than 200% of poverty. One of the major contributors to Open Door's high rate of uninsured patients is the large proportion of undocumented immigrants who do not qualify for Medicaid.

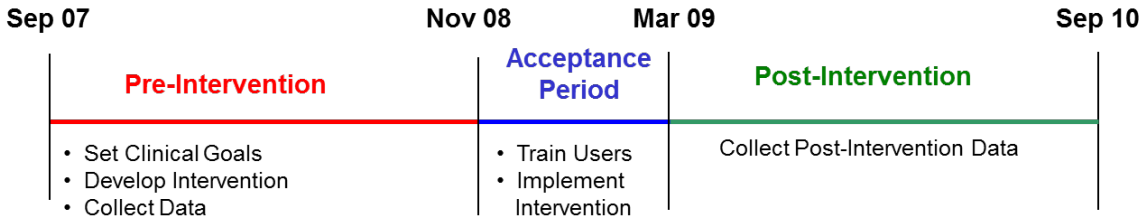
Current Prevalence and Management of Hypertension

Nearly one-third (29.3%) of all Americans suffer from hypertension[18], and while hypertension rates have improved slightly for non-Hispanic whites and African Americans, the Hispanic population has failed to benefit from community-based interventions[19]. According to the Seventh Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC-7) approximately 30% of adults are unaware they have hypertension, more than 40% of individuals with hypertension are not on treatment, and 2/3 of hypertensive patients are not being controlled to recommended levels despite the availability of effective medications and well-published guidelines[1]. The JNC-7 report emphasizes that "undiagnosed, untreated, and uncontrolled hypertension" places "substantial strain on the health care delivery system."

Methods

Our analysis plan included a 15-month pre-intervention period in which hypertension data in the EHR would be collected and analyzed, the providers and staff surveyed and interviewed, and the intervention developed. After 15 months of "EHR-only" use, the intervention comprised of CDSS and provider feedback was implemented at all sites simultaneously. A four-month acceptance period allowed for refinement and full adoption by providers. Fifteen months of post-intervention EHR and follow –up provider data was likewise collected. The study timeline is illustrated in Figure 1.

Figure 1. Study timeline



Interventions

The study team, which included Open Door leadership, providers and staff, (i.e., Chief Medical Officer (CMO), Director of Performance Improvement (DPI), Executive Director and a physician representative) and staff from Primary Care Development Corporation, a nonprofit organization with expertise in practice change and improvement, developed a set of measurable clinical goals related to hypertension management that were based on JNC-7 HTN Guidelines. The goals were agreed to by the clinic's Quality Improvement Committee, and became the basis for the development of the intervention and the set of data to be extracted from the EHR for analysis.

As part of the intervention development, we conducted quantitative and qualitative interviews with all clinical staff and administrative leadership. The results established a baseline for evaluating any changes in attitudes, as well as informed the study team about what tools the providers wanted from the EHR, their facility using the EHR, training needs and other workflow and support issues. The main intervention components included CDSS, provider performance feedback and provider training. Based on the pre intervention interviews, consultation with the study team, and review of the literature, the CDSS features that were ultimately implemented included:

- Alerts, highlighting in red an elevated BP;
- A template, to present the provider with information to be obtained from the patient related to his/her hypertension, and facilitate documentation;
- Medication Adherence Forms, to prompt clinical support staff to ask patients about taking their medications and document the responses;
- An Order Set focused on hypertension, allowing the provider to access a single screen when ordering tests or treatment; and
- Clinical reminders, to prompt providers to screen for tobacco use and/or update indicated tests.

More detail about the CDSS features appears in the Appendix.

To provide individualized performance feedback, the DPI ran quarterly reports on performance measures consistent with the main study outcomes (i.e., percentage of hypertensive

patients with visits in previous quarter whose BP was controlled). The CMO presented the overall performance of each site compared to Open Door's target BP control at a regular quarterly staff meeting. Provider level performance reports were also emailed to providers and they could access their personal report through the EHR.

Training

For clinical staff (PAs, NPs, MDs), the CMO conducted two two-hour trainings. The first included a review of JNC-7 HTN Guidelines and an overview of the hypertension quality initiative, including clinical goals and objectives and available baseline data. At the second training, the CMO and research team demonstrated the new CDSS features, and distributed a customized user manual dedicated to HTN CDSS features. Clinical support staff including MAs, RNs, and LPNs were trained together in a single 45 minute session using a curriculum customized to their roles (e.g., importance of recording height and weight, asking about medication adherence and using CDSS to record assessments).

Aim #1: Effectiveness of Decision Support

Study Design, Data Sources & Collection. We created a longitudinal data base from electronic medical records for all adult, non-obstetric patients. To create patient-level data, we developed a process to extract encounter-level data from eCW's database and create a new data file for analysis. Data from eCW's back-end tables were extracted using BridgeIT®, a data management utility that maps Open Door's EHR data into easily accessed and queried MicrosoftAccess™ software. On a nightly basis, the eCW raw data was extracted, loaded, transformed via BridgeIT and saved in Open Door's stand-alone data warehouse, which was established for this study. Study variables were extracted from the data warehouse for each patient encounter, saved in an Excel file, and transmitted securely to the Data Coordinating Center at Columbia University.

Statistical Analysis. After excluding patients of ethnicities other than Black, White, or Hispanic, and those with more than 30 visits, 3636 patients (28263 encounters) were included in the final analysis. (We left out Asian patients because they accounted for less than 1% of the population and the sample was too small to analyze with any confidence. Based on conversations with the medical staff, we concluded that patients with more than 30 visits (n=44) were outliers and not representative, of the population. Data collected during the intervention adoption period (Nov 2008-March 2009) were excluded from all analyses except for the time series in Figure 2.

Table 1. Sample characteristics

Variable	M ± SD or N (%)‡ Non-Hisp Black (n=712)	M ± SD or N (%)‡ Non-Hisp White (n=717)	M ± SD or N (%)‡ Hispanic (n=2207)	M ± SD or N (%)‡ Total (n=3636)
Age† in years**	52.54 (13.81)	55.06 (13.15)	53.93 (13.68)	53.88 (13.62)
Gender***				
Male	250 (35.1%)	344 (48.0%)	904 (41.0%)	1498 (41.2%)
Female	462 (64.9%)	373 (52.0%)	1303 (59.0%)	2138 (58.8%)
Income***				
Below or equal to poverty line	448 (70.3%)	446 (71.0%)	1739 (82.6%)	2633 (78.1%)
Above poverty line	189 (29.7%)	182 (29.0%)	366 (17.4%)	737 (21.9%)
Number of encounters***	9.31 (5.91)	7.95 (6.51)	8.97 (6.53)	8.84 (6.62)
Average BMI***	32.38 (7.20)	31.16 (6.56)	30.81 (5.67)	31.18 (6.20)
Diabetes ever reported*	214 (30.1%)	173 (24.1%)	1588 (28.1%)	1006 (27.7%)
Average number of prescribed HTN medications at each visit***	1.51 (0.95)	1.31 (0.89)	1.13 (0.81)	1.24 (0.86)

* p<.05
** p<.01
*** p<.001
Notes: Values are means with standard deviations or frequencies with percentages. ANOVA tests were conducted for continuous variables and Chi-square analysis was used for categorical variables. Missing rates were negligible or 0 for all variables.
† Percent within each ethnicity is shown in parenthesis.
‡ Ages are based on patients' first visits during the study period.

The distribution of sample characteristics (Table 1) among Black, White, and Hispanic ethnicities was analyzed using ANOVA tests and Chi-square analysis. A pre- and post-intervention comparison on blood pressure outcomes, as well as clinical process measures, was conducted using ANOVA tests and Fisher's exact tests (Table 2). We also graphed changes in BP control over time using aggregated monthly encounter level data (Figure 2) and conducted an ANOVA test for significance of the BP trends over the 36 month study period.

Figure 2. BP control, June 2007–November 2009

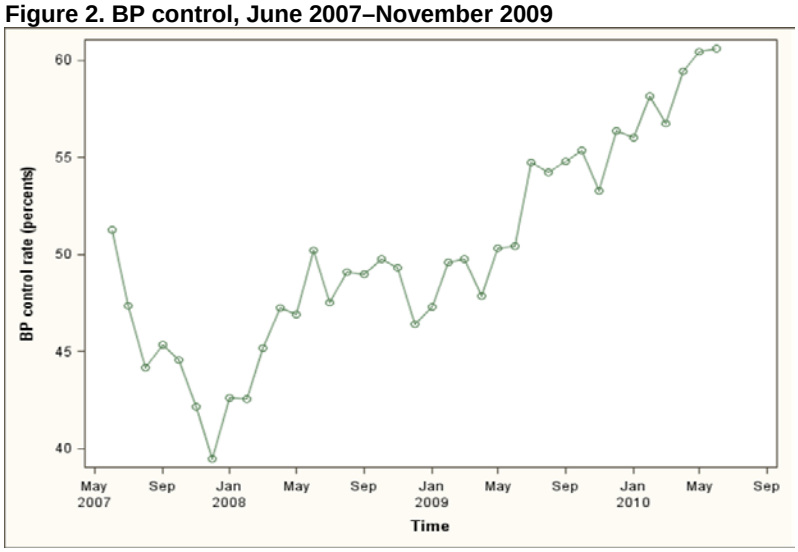


Table 2. Pre and post intervention comparisons of blood pressure outcomes and process measures

Variable	M ± SD or N (%) Pre intervention (n=2697)	M ± SD or N (%) Post intervention (n=2910)
Average SBP***	135.79 (15.60)	132.83 (14.31)
Average DBP**	82.79 (9.93)	81.94 (9.69)
BP control at last visit during each study period***	1370 (50.9%)	1769 (60.8%)
BP control for patients with diabetes† at last visit during each study period***	263 (33.3%)	397 (46.9%)
Had BMET or CMET ***	2132 (79.1%)	2682 (92.2%)
Had ECG***	177 (6.6%)	1520 (52.2%)
Had lipid panel***	1864 (69.1%)	2290 (78.7%)
BMI measured***	1932 (71.6%)	2460 (84.5%)
‡ % follow-up appointment scheduled following guideline when elevated BP observed*	86.94 (27.65)	88.85 (26.60)
% medication started or increased among visits with elevated BP***	27.78 (33.93)	23.58 (33.81)

* p<.05
** p<.01
*** p<.001

Notes: Values are means with standard deviations or frequencies with percentages. ANOVA tests were conducted for continuous variables and Fisher's exact test was used for categorical variables.

† Numbers of patients with diabetes are 789 for pre-intervention period and 846 for post-intervention period.

‡ Open Door defined guidelines for length of time to follow-up visits for patients whose BP was not controlled. Adherence to the guideline included making a follow-up appointment within 12 weeks for patients with Stage 1 BP (systolic 140–159 or diastolic 90–99) at the last visit and within 4 weeks if the patient had Stage 2 BP (systolic >160 or diastolic >100).

A prediction model (Table 3) for BP control at any visit was developed using logistic regression considering the following covariates: age, BMI, gender, income level, race/ethnicity, diabetes status, and the number of hypertension-related medications. Treatment effect is captured by an indicator that takes on a value 1 if the particular visit occurred during the post-intervention period and 0 if the visit occurred during the baseline period. Generalized estimating equations (GEEs)[20] were used to adjust for patients contributing multiple visits to the analysis. Coding for other categorical and continuous variables was based on what yielded the best fit in the univariate model where fit was evaluated using the Quasilikelihood under the Independence Model Criterion[21] which is analogous to Akaike's Information Criterion. The multivariate logistic model was built using a stepwise procedure with an entry/exit p-value of 0.05.

Measures. The primary outcome was BP control before and after the intervention as defined by JNC-7 criteria (BP<130/80 for patients with diabetes or kidney disease; and BP <140/90 for all other patients). This was analyzed at the patient level and the encounter level. At the patient level, we report pre and post intervention mean systolic and diastolic blood pressures (SBP, DBP) and the proportion of patients with BP controlled at the last visit at both time periods (Table 2). The process measures included the proportion of patients who had a documented BMI, ECG, lipid profile and nutrition visit in each study period, timeliness of follow-up visits when the BP was out of normal range and medication intensification, defined as the percentage of visits with a new medication added, titration of the original antihypertensive medication or both, among visits with an elevated BP. To ensure accuracy and validity of blood pressure measurement and recording in the EHR (in addition to avoiding misdiagnosis), a retraining of clinical staff via on-line tutorial was undertaken in November 2007.[22]

Table 3. Multivariate logistic regression model using generalized estimating equations to predict hypertension control at each encounter

Variables	OR (95% CI)	P value
Diabetes	0.33 (0.29-0.37)	<.0001
Number of Prescribed Hypertensive Medications	0.84 (0.80-0.88)	<.0001
Post intervention	1.50 (1.36-1.66)	<.0001
BMI	0.97 (0.96-0.98)	<.0001
Ethnicity		.010
Black	1.0 [Reference]	
Hispanic	1.22 (1.05-1.42)	.009
White	1.32 (1.09-1.61)	.005
Female	1.30 (1.16-1.46)	<.0001
Income		.053
< 100% of poverty level	1.0 [Reference]	
100-150% of poverty	0.94 (0.82-1.09)	.416
150-200% of poverty level	0.70 (0.53-0.91)	.009
> 200% of poverty level	1.00 (0.80-1.24)	.979

Notes: The fact that each participant contributed to multiple encounters is adjusted. Variables are presented in the order in which they were entered into the model. OR = Odds Ratio; CI = Confidence Interval. There were 28263 encounters among the 3636 patients with hypertension. However, because of missing data, complete data for the multivariate model was available for 12495 encounters.

Limitations. There are several limitations to this analysis. First, the study did not include a control condition, however our analyses, both the trend analysis and predictive multivariate model, strongly suggest that the intervention impacted patient outcomes. We conducted several additional analyses (not shown) that increase confidence in the findings. For example, we examined the trends over the 36 month study period in BP control of only new patient visits and found that they remained below 50% indicating that increases in BP control were not related to new patients who might have entered the CHCs with well controlled BP. We also examined BP control pre and post intervention among only those patients who had at least one visit in both study periods and also among patients who were only in the baseline compared to those only in the post intervention period (cross sectional analysis). Each of these analyses demonstrated significant improvements in BP control. Second, the longitudinal design is unbalanced meaning that BP values are not observed at distinct time points and not all patients contributed the same number of BP measurements. However, the model adjusts for this discrepancy. Finally, we were not able to consistently and reliably collect data on the use of the CDSS. Our post intervention interviews with providers did offer insights into system use however; this area requires further study.

Findings. Table 1 shows the characteristics of patients with a diagnosis of hypertension that had at least one visit during the study period. Patients had an average of 8.84 (SD=6.62) clinic visits during the 36 month study period (mean of 5 visits both pre and post intervention). All characteristics were significant associated with race/ethnicity. As shown in Table 2, average SBPs and DBPs were significantly lower in the post intervention period compared with pre intervention. Rates of BP control at the last visit during each study period also improved from 50.9% pre-intervention to 60.8% post-intervention. Significant improvements in BP control were also observed among patients with diabetes (33.3% at pre-intervention and 46.9% at post intervention). However, rates of BP control remained lower than among patients without diabetes. Table 2 also shows significant improvements in all process measures except medication intensification. Medication intensification declined from 28% at pre-intervention to 24% at post-

intervention period. Figure 2 shows the trend of monthly cross-sectional measures toward improved hypertension control over the course of the study. This trend is statistically significant ($p<.001$). We hypothesize that the initial downward trend is related to Open Door's migration of BP data from charts to the EMR in May 2007. For existing patients with paper charts, only the last BP measure was entered in the patient's newly created electronic medical record, making them "new" to the EMR system, although not new to Open Door and therefore not new to treatment. Truly new patients, those with records created after May 2007, have not been treated, and are therefore more likely to have uncontrolled BP, causing a drop in the overall percentage of controlled BP encounters. As new patients are treated, the overall control rate returns to baseline, and then continues upward following the implementation of the CDS.

Controlling for other factors that were significantly associated with BP control, in Table 3, the logistic regression model shows that patients were 1.5 times more likely to have BP controlled post intervention than pre intervention. Correlates of poor BP control were black race, female gender, income, higher BMI, diabetes and larger number of prescribed antihypertensive medications.

Aim #2: Factors that Influence Adoption

Study Design, Data Sources & Collection. We used a mixed methods approach including in-depth interviews of staff and direct observations of patient flow and staff functions to assess the degree to which the intervention is integrated into practice as intended and to clarify the mechanisms through which the intervention operated to influence staff behavior.

Semi-structured individual interviews were conducted with participating primary care providers (n=16) before and after the intervention and with key informants involved in implementing the intervention (n=6) after the intervention. The interviews were conducted by the evaluators and lasted about 30-45 minutes. They were audio-recorded and transcribed for analysis. The interview questions focused on perceptions and experiences regarding hypertension care, hypertension guidelines, electronic health records, organizational environment, intervention components and intervention implementation. Interview transcripts were coded systematically using Atlas.ti qualitative analysis software. A team of four researchers developed a set of codes in an iterative process and all transcripts were then subjected to systematic coding. Ten percent of transcripts were coded by two researchers to verify agreement.

Measures: Provider and Key Informant Interviews. Providers practicing at the four health centers (n=16) were interviewed about 6 months prior to and at 3-4 months following the launch of the intervention. The interview questions focused on perceptions and experiences regarding hypertension care, hypertension guidelines, electronic health records, organizational environment, intervention components and intervention implementation. Key informants (n=6) representing leadership and staff actively involved in implementation of the intervention were interviewed about the implementation experience about 5-6 months after the intervention began. The semi-structured interviews were conducted by the evaluators and lasted about 30-45 minutes. They were audio-recorded and transcribed for analysis. Human subject participation was approved by the Institutional Review Boards at New York University and Columbia University Medical Center. Informed consent was obtained from all interview participants.

Data Analysis. Interview transcripts were coded systematically using Atlas.ti qualitative analysis software. A team of four researchers developed a set of codes in an iterative process and all transcripts were then subjected to systematic coding. Ten percent of transcripts were coded by two researchers in order to verify agreement.

Limitations. While our qualitative study provides insight into processes common across health care settings, it has limited generalizability. In particular, the intervention was implemented in a setting that stands out for its innovativeness and positive quality improvement culture among similar CHCs. Qualitative interviews of participants can be a highly useful and valid methodology to understand why a multi-component intervention worked, but there are limitations stemming from the subjectivity with which participants interpret the causes of success. Another methodological limitation is the lack of quantitative data on use of the EHR-based intervention components. Future studies should pursue access to such data from the back-end of the EHR system. We used qualitative process evaluation to understand why our intervention worked. We cannot attribute the success of the intervention to any particular component or set of components.

Results

Findings. Three main domains emerged in light of process evaluation research questions and implementation theories: 1. Satisfaction and perceived usefulness of intervention components, 2. Perceived proximal changes resulting from the intervention, and 3. Perceived facilitators of change. Each of these contributes answers as to why the intervention had a successful outcome.

1. Satisfaction and Perceived Usefulness of Intervention Components. Assessing satisfaction among participants (or users) is a staple of process evaluation. The Technology Acceptance Model (TAM) construct of "perceived usefulness", which is widely used in IT research[23], broadens an assessment of satisfaction to include reasons why the person likes an IT tool, and in particular how it facilitates work activities. When asked why they liked the different intervention components, the providers phrased their answers in terms of perceived usefulness. The interviews prompted respondents about their satisfaction with each of the five major intervention components: alert, order set, template, clinical reminders and provider feedback reports. In addition, respondents reported on their satisfaction with the training associated with the intervention and the development of hypertension guidelines tailored for the CHC.

Table 4. Satisfaction and perceived usefulness of intervention components

Intervention Component	Findings	Representative Quote(s)
Alert	Having elevated blood pressure readings listed in red was generally well-liked and considered highly effective in bringing attention to blood pressure.	It does help. Sometimes you may just glance over, but when it's red it does stand out much more. Especially when the blood pressure was just, say, 130 over 90, a lot of times we would have just ignored it, but having that red does help.
Order Set	The hypertension order set was not universally endorsed but some providers found it very useful. It was reported as helpful for remembering recommended orders and validating the treatment plan	I sometimes try to remember to use that order set because I do find that that helps me track when labs were done. That to me is the most helpful. I like to be validated in what I do, and since this is not my typical patient that I see, I like to see that. The little hint for the labs, the immunizations and the appointments are all the pros of it.
Template	Most providers elected not to use the hypertension template but some liked it and became regular users. Use of a template and order set, or neither, varied based on the provider's documentation style and expertise level. Several providers particularly liked the ease of accessing patient education materials through the template	With the new hypertensives I use it because I really like the patient education.
Clinical Reminder	Some providers found the reminders triggered by the decision support algorithm particularly helpful. They were found effective in catching what might have been missed	It gives you the real little tips, the hints, and what you missed, which is great.
Performance Feedback	Satisfaction with the feedback reports (known in the clinic as "provider report cards") was mixed. While some providers questioned the validity and reliability of the entire methodology, others felt that this was the most effective intervention component. The report cards were seen as promoting vigilance and aggressive action with hypertension patients.	If I see I'm not performing as well as my colleagues they must be doing something more than I am, so I need to be more aggressive. I don't think that those report cards are that fair or accurate.
Other Components Training and Definition of Hypertension Guidelines	The training sessions were seen as helpful in conveying information and in rallying everyone around a common goal to address hypertension and in motivating buy-in across the organization. Providers also felt that it was important that "the standards are put on paper for us", referring to the process of defining hypertension guidelines that were tailored to their health center. Together with the trainings, the guidelines facilitated getting everyone in the organization "on the same page".	The training session that we had was a big thing. We all came together as a team. It was a whole team approach.

2. Perceived Proximal Changes Resulting from the Intervention. This domain corresponds with questions about short-term or intermediate outcomes. The DeLone & McLean model of IT implementation[24] was used to conceptualize proximal change in provider and organizational behavior. The pertinent interview segments were those where providers described what they were doing differently in hypertension care as a result of the intervention.

Table 5. Perceived proximal changes resulting from intervention

Proximal Change	Finding	Representative Quote
More Aggressive Care	The interview responses consistently indicated that providers believed the intervention led them to be more aggressive in their management of hypertension.	I am a lot more aggressive in hypertension care. We're all in that mode. That's my vibe is that we're really trying to get this in control. I guess I'm like the hypertensive police now, in that mode. I've been on this kick now that I have to give patients print-outs. And it's available on that order set in English and in Spanish.
More Systematic, Consistent Care	A pattern closely related to more aggressive patient management was the provision of care that was more consistent with guideline recommendations. For example, providers reported ordering EKGs more regularly for hypertensive patients and being more likely to schedule follow-up visits at recommended intervals.	We're doing more EKGs. I don't think we were routinely doing that for every hypertensive patient. Now we are trying to have one on record for every single hypertensive patient, so that is something that's new. I think the follow-ups - that's really impacted. Because it's all spelled out when they should come back. I think before I wasn't really thinking of, oh in three months rather than six months or four months.
More Overall Attention to Hypertension	Several respondents spontaneously commented that the success of the intervention was due to a combination of many factors coming together.	I think it's a combination of everything. Medical assistants are reminding us, oh, he's a hypertensive and he hasn't done an EKG yet. The patient advocates. We're more aware of abnormal blood pressures. It's a combination of everything. I don't think it's just one or two things. What we've been concluding is that there are many different pieces to this sort of package that we're implementing here and that it's just overall these things together plus just paying more attention to hypertension. That seems to be making a difference here.

3. Perceived Facilitators of Change. IT implementation models, such as the TAM[23]and Overtveit's model[25] posit factors that serve as facilitators of successful implementation. Drawing on these models, we found six facilitators that emerged as important for our implementation:

    - Leadership: Full buy-in and participation by top leadership of the health centers was seen as critical;

    - Organizational Culture: Several participants noted that their organization was "amenable to change" and particularly hospitable to quality improvement;

    - Provider Engagement: Provider input was actively sought during intervention design and implementation;

    - Rigorous Implementation Process: more rigorous compared to other quality improvement initiatives at the CHC, participants described the process as "methodical", "systematic", "comprehensive" and "persistent;

    - Framing of Intervention as Quality Improvement: the project was presented as "a special quality improvement project;" and

- Health Center Capacity to Process Data: with assistance from an IT consultant hired by the CHC, it was possible to produce clean and reliable "provider report cards" as well as the data the researchers used to measure patient outcomes of the intervention.

Discussion

Three aspects of the study appear to stand out as critical to improving hypertension care and outcomes in this setting: 1) the multicomponent nature of the intervention, 2) the consideration of the practice context and local concerns, and 3) the framing of the intervention as part of a comprehensive quality improvement initiative.

Multicomponent Intervention. We found that a multicomponent intervention that included CDSS and provider performance feedback promoted adherence to hypertension clinical guidelines and was associated with improvements in blood pressure control. The systematic qualitative process evaluation illuminated the reasons why the intervention improved hypertension control. Among the CDSS features, there was something that worked for everyone. Our evidence suggests it was the synergy of the intervention components that lead to the positive outcomes. Similarly, impact on care processes was perceived to manifest in many different ways. The changes participants described in care practices were consistent with the quantitative process measure outcomes.[26] Part of the impact of the quality improvement project was described as an increase in "overall attention to hypertension" and being generally "more aggressive". Again, participants believed that it was the combination of several changes that contributed to the overall outcome. We interpret these findings to mean that it is precisely this multifaceted approach that explains success in improving the outcome of hypertension control.

Practice Context. A lack of attention to practice context and unique conditions can impede effective adoption of QI interventions.[27] Our process to tailor the QI intervention, which included pre and post intervention interviews with providers to assess agreement with guideline recommendation and other factors associated with adoption of CDSS, allowed the sites to translate the guideline into local standards of practice.[23,28,29,30] Based on findings from post intervention qualitative interviews with providers, this process enabled a closer fit between the goals of the intervention and practice conditions.[31] In designing and implementing the CDSS, the study team involved the users in specifying the CDSS functions for each clinical objective.[5,27,32] More specifically, the study team went through a systematic process adapted from Osheroff and informed by two health IT implementation models (TAM and Overtveit's model) to select features based on how easy it would be to build within the current eCW platform, on skills, resources and preferences of the clinic and the usability, acceptability and ease of use from the provider's perspective.[23,28,29]. Open Door's CDSS had many of the features found to effect quality of care[11] (see Appendix). In addition, the system required minimal training, offered several methods for obtaining similar information allowing providers to choose from a menu of options to obtain information, and did not mandate practice patterns.

Quality Improvement Framework. Health IT tools were embedded in a quality improvement framework that allowed for a comprehensive organizational approach to improving hypertension care. Health IT tools often fail to improve health outcomes[33] but that may be partly because they are implemented as circumscribed interventions that do not become part of the

context of a quality improvement effort. Additionally, consistent with the chronic care model for systems level quality improvement, the CDSS was viewed as being only one component of practice change needed to reach the targets for each quality indicator.[34] For example, the CDSS provided opportunities for changes in the clinical team's responsibilities. Staff were trained to use the new CDSS to screen for adherence to medications, removing this task from the provider and engaging clinical support staff in this dimension of patient care. In a recent review of quality improvement strategies for improving blood pressure control, team changes (e.g. creating new roles), was one of three strategies associated with the largest effects.[9] Several other factors were identified as facilitators of success. They included organization culture, leadership, rigorous implementation process, provider engagement and the health care setting's ability to process patient data. Strength in these areas is more likely to make health IT interventions successful.

Implications

The lessons learned about health IT adoption as stated in the FOA have been borne out: implementation is one part technology and two parts organizational culture and workflow change, a systems approach to changing the team is required, and stakeholders need to see what value the new systems offer. More importantly, however, is the demonstration that when these lessons are taken to heart, and the implementation is guided by organizational and cultural environments, and perceived value of technology, health IT can play a central role in improving adherence to care standards and clinical outcomes. Ambulatory care users must be prepared to develop organizational characteristics and engage in the activities that lead to success in using IT: strong leadership, an organizational culture of improvement, involved providers, the capacity to access and use EHR data, and a focused, rigorous implementation process. The better these lessons are understood by payers, technology vendors, government agencies, policymakers, and other stakeholders, the more likely the success of the implementation and use of health IT for quality and safety.

Conclusion

In this study we used qualitative and quantitative methods to meet AHRQ's three major goals of the IQHIT FOA:

- Assessing the impact of health IT on outcomes in ambulatory settings
- Investigating novel methods and evaluating existing strategies for clinician use of health IT in ambulatory settings; and
- Devising strategies for safe, successful health IT adoption.

We demonstrated *impact* on both intermediate care processes as well as patient outcomes by applying known lessons about the delivery of evidence to the point of care. Our study showed improved adherence to guidelines and more aggressive, systematic, and focused attention on a priority condition—hypertension—on the part of providers using CDSS. Our study furthered the *investigation and evaluation of methods* to assess the success of health IT, by utilizing

quantitative analyses to measure impact but also qualitative approaches that served to capture the "hows" and "whys" of success, and also engender buy-in by providers who are not always asked for their input. Finally, this project proposes *strategies* to foster the adoption of health IT, especially among ambulatory care providers. Winning strategies, based on our results, entail using a multifaceted approach to account for local and individual preferences, and to create a "buzz" about improving performance. A rigorous, systematic implementation should take into account the practice context, so that the right CDSS features are deployed. Finally, CDSS adoption should be framed as *quality improvement*, where system-level practice changes, new roles, the obtaining and use of data, and other demands are facilitated by strong leadership, provider and staff engagement, and organizational culture of learning.

Other IOM Required Outcome Measures

Information pertaining to the Institute of Medicine's priority areas is summarized below.

1. Are patients able to access quality and safety reports for their providers? No, the Board gets these reports in the aggregate—not by specific MD.

2. Do patients report their experience with care? Yes. Open Door has a system-wide survey that is administered once a year. This will be changing as Open Door brings on CAPHS in 2012.

3. What % of patients have access to their personal health information? 0 Open Door plans a patient portal in 2012 which will provide some access to PHI.

4. What % of providers use measurement (surveys) to evaluate their patients' experience? Open Door is currently piloting the NCQA CAPHS survey to ask about patient experience specific to each physician.

5. Has patient experience data been shared with the national repository for data from the CAPHS surveys? Not yet.

6. What quality measurement reports do your providers have access to? Measurements around diabetes, asthma, hypertension, prenatal care, well child care, cancer screenings, smoking cessation, and BMI.

References

1. Ambulatory Safety and Quality Program: Improving Quality Through Clinician Use of Health IT (R18). December 2006. Agency for Healthcare Research and Quality. Rockville, MD. http://grants.nih.gov/grants/guide/rfa-files/RFA-HS-07-006.html

2. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension*. 2003;42(6):1206-1252.

3. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. *JAMA*. 2010;303(20):2043-2050.

4. Frijling BD, Lobo CM, Hulscher ME, et al. Intensive support to improve clinical decision making in cardiovascular care: a randomised controlled trial in general practice. *Qual Saf Health Care*. 2003;12(3):181-187.

5. Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients' care. *Lancet*. 2003;362(9391):1225-1230

6. Oxman AD, Clarke MJ, Stewart LA. From science to practice. Meta-analyses using individual patient data are needed. *JAMA*. 1995;274(10):845-846.

7. Roumie CL, Elasy TA, Greevy R, et al. Improving blood pressure control through provider education, provider alerts, and patient education: a cluster randomized trial. *Ann Intern Med*. 2006;145(3):165-175.

8. Shojania KG, Ranji SR, McDonald KM, et al. Effects of quality improvement strategies for type 2 diabetes on glycemic control: a meta-regression analysis. *JAMA*. 2006;296(4):427-440.

9. Walsh JM, McDonald KM, Shojania KG, et al. Quality improvement strategies for hypertension management: a systematic review. *Med Care*. 2006;44(7):646-657.

10. Garg AX, Adhikari NK, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. 2005;293(10):1223-1238.

11. Kawamoto K, Houlihan CA, Balas EA, et al. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. 2005;330(7494):765.

12. Bryan C, Boren SA. The use and effectiveness of electronic clinical decision support tools in the ambulatory/primary care setting: a systematic review of the literature. *Inform Prim Care*. 2008;16(2):79-91.

13. Bosworth HB, Olsen MK, Dudley T, et al. Patient education and provider decision support to control blood pressure in primary care: a cluster randomized trial. *Am Heart J*. 2009;157(3):450-456.

14. Hicks LS, O'Malley AJ, Lieu TA, et al. The quality of chronic disease care in U.S. community health centers. *Health Aff* (Millwood). 2006;25(6):1712-1723.

15. Murray MD, Harris LE, Overhage JM, et al. Failure of computerized treatment suggestions to improve health outcomes of outpatients with uncomplicated hypertension: results of a randomized controlled trial. *Pharmacotherapy*. 2004;24(3):324-337.

16. Hicks LS, Sequist TD, Ayanian JZ, et al. Impact of computerized decision support on blood pressure management and control: a randomized controlled trial. *J Gen Intern Med*. 2008;23(4):429-441.

17. Department of Health and Human Services. Federal Register Vol 75. 2010; http://edocket.access.gpo.gov/2010/pdf/2010-17207.pdf, August 15, 2011.

18. Ong KL, Cheung BMY, Man YP, et al. Prevalence, awareness, treatment, and control of hypertension among United States adults 1999-2004. *Hypertension*. 2007;49:69-75.

19. Qureshi AI, Suri MF, Kirmani JF, et al. Prevalence and trends of prehypertension and hypertension in United States: national health and nutrition examination surveys 1976 to 2000. *Med Sci Monit*. 2005;11:403-9.

20. Liang K-Y ZS. Longitudinal data analysis using generalized linear models. *Biometrika*. 1986;73:13-22.

21. Pan W. Akaike's information criterion in generalized estimating equations. *Biometrics*. 2001;57:120-125.

22. Blood Pressure Measurement Recommendations of the British Hypertension Society; http://www.abdn.ac.uk/medical/bhs/index.htm, September 14, 2011.

23. Venkatesh V, Morris MG, Davis GB, et al. User acceptance of information technology: Toward a unified view. *MIS Quart*. 2003;27(3):425-478.

24. DeLone WH, McLean ER. The DeLone and McLean model of information systems success: A ten-year update. *J Manag Inform Syst*. 2003;19(4):9-30.

25. Ovretveit J, Scott T, Rundall TG, Shortell SM, Brommels M. Implementation of electronic medical records in hospitals: Two case studies. *Health Policy*. 2007;84(2-3):181-190.

26. Shelley D, Tseng, TY, Matthews A, et al. A technology-driven intervention to improve hypertension outcomes in community health centers. Unpublished observations.

27. Ruhe MC, Carter C, Litaker D, et al. A systematic approach to practice assessment and quality improvement intervention tailoring. *Qual Manag Health Care*. Oct-Dec 2009;18(4):268-277.

28. Ovretveit J, Scott T, Rundall TG, et al. Improving quality through effective implementation of information technology in healthcare. *Int J Qual Health Care*. Oct 2007;19(5):259-266.

29. Osheroff JA TJ, Pifer EA, et al. ed *Improving Outcomes with Clinical Decision Support: An Implementer's Guide*. HIMSS; 2005.

30. Robinson JC, Casalino LP, Gillies RR, et al. Financial incentives, quality improvement programs, and the adoption of clinical information technology. *Med Care*. Apr 2009;47(4):411-417.

31. Millery M SD, Tseng T, Wu D, et al. Qualitative Evaluation to Explain Success of Multifaceted Technology-driven Hypertension Intervention. *Am J Managed Care*. submitted.

32. Minkler M. Community-based research partnerships: challenges and opportunities. *J Urban Health*. Jun 2005;82 (2 Suppl 2):ii3-12.

33. Millery M, Kukafka R. Health information technology and quality of health care: Strategies for reducing disparities in underresourced settings. *Med Care Res Rev*. 2010;67(5 suppl):268S-298S.

34. Wagner EH AB, Davis C, Hindmarsh M, et al. Improving chronic illness care: translating evidence into action. *Health Affairs (Millwood)*. 2001;20(6):64-78.

List of Publications and Products

Dissemination Activities

H Kopal, D Wu. CDS and the Management of Hypertension in a Community Health Center. Community Health Center Association of New York State Annual Conference; 2011 October 17 -19; Saratoga Springs, NY. [scheduled]

D Shelley. CDS and the Management of Hypertension in Federally Qualified Health Centers. Practice-Based Research Network (PBRN) Annual Research Meeting; 2011, June 24; Bethesda, MD.

H Kopal. CDS and the Management of Hypertension in a Community Health Center. 2011 June 21 Webinar

D Wu. Using CDS to Improve Hypertension Control. 2011 eClinicalWorks Health Center Symposium; 2011 June 13 - 14; Marlborough, MA.

H Kopal. CDS and the Management of Hypertension in a Community Health Center. AcademyHealth Annual Research Meeting; 2011 June 12 – 14; Seattle, WA.

L Farrell. Beyond Implementation: Leveraging the EHR for the Greater Good! Healthcare Information and Management Systems Society (HIMSS) Annual Conference and Exhibition; 2011 Feb. 20 – 24; Orlando, FL.

H Kopal, D Wu. CDS and the Management of Hypertension in a Community Health Center. New York Association of Ambulatory Care; 2010 June 12; New York, NY.

H Kopal. Using EHR-enabled CDS to Manage Hypertension in a Community Health Center: The

Providers' Perspective; AHRQ Annual Health IT Grantee and Contractor Meeting; 2010, June 2 – 4; Bethesda, MD.

P Ferrari. Use of Computerized Clinical Decision Support System and Registry Functions to Track and Improve Clinical Outcomes. eClinicalWorks 2009 National Users Conference; 2009 Sep 12 – 15, Las Vegas, NV.

H Kopal. Evaluation of CDS and EHR Registry to Improve Management of Hypertension in a Community Health Center. AHRQ 2008 Annual Conference; 2008 Sep 8 – 10; Bethesda, MD.

Products

In addition to the pre-intervention provider survey and interview tools previously submitted to AHRQ, products from this study include:

Kopal H, Sacks R, Shelley D. *Translating Evidence into Action: A How-To Manual for Implementing Clinical Decision Support*, July 2011.

Shelley D , Tseng T, Andrews, H, et al. Predictors of Blood Pressure Control Among Hypertensives in Community Health Centers. *American Journal of Hypertension* (2011). doi:10.1038/ajh.2011.154

Shelley D , Tseng T, Matthews, A, et al. Technology-Driven Intervention to Improve Hypertension Outcomes. [manuscript under review by the *Journal of Managed Care*, Special IT Issue]

Millery M, Shelley D, Wu D, et al. Qualitative Evaluation to Explain Success of multifaceted Technology-Driven Hypertension Intervention. [manuscript under review by the *Journal of Managed Care*, Special IT Issue]

Appendix

Open Door CDS System Features

General system features

Feature	Examples
Integrated with charting or order entry system to support workflow integration*	Template is part of charting process, HTN treatment options based on guidelines appear in Order Set
Multiple types of suggestions**	Notifications and alerts provided in different ways including reminders of overdue tasks, alerts, pre-loaded medication lists
Variable Degree of Automation**	User receives prompts upon active initiation of order set, template, or reminders; out-of-range BP alert is automatic

Clinician-system interaction features

Feature	Examples
No need for clinician data entry for CDSS use only*	Reminders are generated based on standard clinical documentation
Provision of decision support as part of clinician workflow*	Out-of-range BP entered in vitals screen and appearing in red in progress note
Provision of decision support at time and location of decision making*	Medications and laboratory test options provided on screen as part of order set
Recommendations executed by noting agreement*	Overdue laboratory tests recommended on order set; clinician checks box to order test
Allows taking recommended action rather than adding new steps***	OS presents recommendations for tests, meds and follow-up visits and allows clinician to order them directly
Prompts can be individualized by each user***	Clinicians can design and implement their own templates for obtaining HPI for HTN; Order sets can be set up as “favorites”
Selected information collected and stored as structured data to ensure consistency and enable reporting***	Medication, dietary, self-management, and exercise adherence forms provide checkboxes for patients’ responses
Access to CDS features appear in multiple locations in EMR***	Order set and CDSS reminders can be accessed in 3 ways; 2 prior to diagnosis, and 3rd added once diagnosis is made

Communication content features

Feature	Examples
Justification of decision support via provision of reasoning*	Reminder to order diagnostic tests based on date of last exam
Justification of decision support via provision of research evidence*	Guideline justification available in Order Set
Provision of a recommendation, not just an assessment*	Order Set presents recommended (though not required) medications, lab tests and follow up guidelines
Allows documentation of the reason for not following CDSS recommendations*	CDS reminders enable entry of reason for not following; CDS allows user to suppress reminder or snooze to later date
System includes branching logic to prompt user based on data values entered***	Smart forms for tobacco use presents patient questions based on previous responses and enables access to Fax-to-Quit feature

Auxiliary features

Feature	Examples
User involvement in development process*	System developed by local clinic staff input
System designed through iterative refinement process*	System designed finalizes after testing with representatives from targeted user group; refinement ongoing based on user feedback
CDSS accompanied by periodic performance feedback*	Clinicians received quarterly reports summarizing the proportion of HTN patients with controlled BP at last visit
CDSS accompanied by conventional education*	Clinicians received retraining on BP measurement, organizational procedures for managing HTN, and JNC-7 guidelines

* features identified by Kawamoto

** features identified by Damiani; G Damiani, L Pinnarellli, S Colosimo, et al. The effectiveness of computerized clinical guidelines in the process of care: a systematic review. *BMC Health Services Research*. 2010 10:2

*** features identified by authors