# Impact of Electronic Diabetes Registry Use on Care and Outcomes in Primary Care

*Research-in-Progress*

**Wencui Han**
University at Buffalo
wencuihan@gmail.com

**Raj Sharman**
University at Buffalo
raj.sharman@gmail.com

**Arvela Heider**
HEALTHeLINK
arvela@holark.com

**Nancy Maloney**
HEALTHeLINK
nmaloney@wnyhealthelink.com

**Gurdev Singh**
University at Buffalo
gsing4@buffalo.edu

**Ranjit Singh**
University at Buffalo
rs10@buffalo.edu

## Abstract

This paper examines the impact of using disease registry meeting meaningful use criteria. We specifically examine the impact of the use of a) registry for patient reminders and b) registry for quality improvement on the quality of care and hospital utilization. Registries are essentially IT artifacts features within Electronic Medical Record (EMR) systems. Patient records from 51 urban practices and 12513 patients suffering from type II diabetes were analyzed. The results suggest that for patients without congestive heart failure, the use of disease registry is significantly associated with improvement of quality of care and lower hospital utilization rate. Based on the analysis of the data, this paper develops a series of propositions for future confirmatory analysis to establish causality.

## Keywords

Disease registry, diabetes, meaningful use, quality improvement

## Introduction

Chronic diseases are placing a growing burden on the health care system. Health care providers are seeking ways to better manage patients with chronic diseases. Registries are essentially IT artifacts features within Electronic Medical Record (EMR) systems, and are important tool o manage patients with chronic diseases. This paper examines the impact of using disease registry meeting meaningful use criteria. We specifically examine the impact of the use of a) registry for patient reminders and b) registry for quality improvement on the quality of care and hospital utilization. By analyzing patient records from 51 urban practices and 12513 patients suffering from type II diabetes, the results suggest that for patients without congestive heart failure comorbidity, the use of disease registry is significantly associated with improvement of quality of care and lower hospital utilization rate. Based on the analysis of the data, this paper develops a series of propositions for future confirmatory analysis to establish causality.

The prevalence and incidence of diabetes mellitus have been increasing substantially in the United States as a result of multiple factors including increasing obesity, aging, and demographic changes.

According to Centers for Disease Control and Prevention (CDC), in 2010, nearly 26 million people, 8.3% of the US population, were affected by diabetes(FIDIS, 2013). Total prevalence is projected to increase to 21% to 33% of the US adult population by 2050 (Boyle et al, 2010).

Diabetes is a chronic disease with serious complications. Medical expenses for people with diabetes are 2.3 times higher than for people without diabetes. The total estimated diabetes costs in the United States in 2007 was $174 billion (American Diabetes Association, 2008). These findings underscore the urgency of improving diabetic care and reducing diabetes-related economic burden.

The meaningful use (MU) of electronic health records is expected to improve health outcomes and lower the cost of care(Adams et al, 2003; Wang et al, 2003). "Meaningful use" is using certified electronic health record (EHR) technology to: "Improve quality, safety, efficiency, and reduce health disparities; Engage patients and family; Improve care coordination, and population and public health; and Maintain privacy and security of patient health information". The potential of MU of EHR to facilitate implementation of chronic disease care models to improve care quality and efficiency is well recognized (Chaudhry et al, 2006; Young et al, 2007; Hillestad et al, 2005). However, MU functionalities have been applied to varying degrees in practices and there is uncertainty about the relative impact of specific EHR functions/tools on chronic disease care and patient outcomes.

Disease registries are one potentially important EHR tool for the management of patients with chronic diseases (Metzger, 2004; Schmittdiel et al, 2005; Ortiz, 2006; Maizlish and Herrera, 2005). A chronic disease registry is created to "capture, manage, and provide information on specific conditions to support organized care management of patients with chronic disease" (Metzger, 2004). Well designed disease registries should be able to integrate a variety of information including patient demographics, laboratory results, pharmacy data, and comorbidity data to serve a variety of functions outside of the clinical encounter. Electronic registries have become an essential technological component of the patient centered medical home model (PCMH) (Goldberg and Kuzel, 2009; Nutting et al, 2009). In the MU regulations, two separate but related registry functions are described (as core items in both Stage 1 and Stage 2 MU) namely: (a) to identify patients who should receive reminders about needed care (such as recommended laboratory testing for diabetic patients) and (b) to provide quality measurement to drive improvement.

Diabetes chronic disease registries have been studied in the past demonstrating effectiveness in improving a limited set of care processes (Stroebel et al, 2002; Karter et al, 2004; Renders et al, 2001; Harris et al, 2002). Based on the existing evidence, a computer simulation model developed by Bu. et al estimated that diabetes registries could save $14.5 billion in health care expenditure over 10 years (Bu et al, 2007). This is an exciting result but it should be noted that it is based on extrapolation of evidence of care process improvement to predict improvements in health outcomes. Data showing a direct relationship between diabetes registry use and key health outcomes are lacking.

This study aims to make progress in understanding potential benefits of diabetes registry use in various ways. First, we evaluate care quality, in a more comprehensive way, using HEDIS (Healthcare Effectiveness Data and Information Set) comprehensive diabetes care process measures, including HbA1C testing, LDL screening, Eye exam, Nephropathy screening. HEDIS is a widely used set of health care performance measures that is developed and maintained by the National Committee for Quality Assurance (NCQA). In addition, we directly examine acute care hospitalization as an important and costly outcome of diabetes, specifically measuring avoidable hospitalization and ED visits. Finally, we attempt to differentiate between two different types of registry use for diabetes care, namely the generation of patient reminders, and quality improvement, corresponding to two core MU requirements.

This study was conducted in the context of the Beacon project, funded by the Office of the National Coordinator for Health Information Technology (ONC). In the Beacon Community, diabetes registries were already being used by some practices prior to the start of the Beacon project. Based on anecdotal reports, they were thought to be beneficial. For this reason, and in keeping with the mandates of MU and PCMH, use of diabetes registries in primary care was chosen as one of the key interventions to be rolled out across the community with Beacon funding. The data presented in this paper is an attempt to better understand the impacts of the 'Pre-Beacon' use of diabetes registries. Future work will examine the impacts of registries in the context of the overall Beacon intervention.

## Method

### *Study Population and Setting*

This study is part of the Beacon Community Cooperative Agreement Program (Beacon project) funded by the HHS Office of the National Coordinator for Health IT (ONC). The Beacon project aims to demonstrate how health IT investments and MU of EHRs advance the vision of patient-centered care, while achieving the 'triple aim' of better health, better care, and lower cost. The Clinical Information Exchangea is a Beacon Awardee. The Beacon project focuses on adult diabetic patients in eight counties, including urban, suburban, and rural areas.  All urban practices enrolled in the Beacon project were eligible for inclusion in this study.

### *Data sources*

This study uses secondary data from two sources. First, at the beginning of the Beacon project (2010 to 2011), Beacon community partners surveyed primary care practices regarding existing HIT adoption and use, including the adoption status of diabetes registries. The survey was administered in person to one or more key practice members with clinical, administrative, and/or IT leadership responsibilities. The survey was completed as a group if there was more than one interviewee.

Second, aggregated claims data for calendar year 2010 were obtained from the three largest payers in the community. This included all plans operated by each payer, including Medicare and Medicaid managed care programs. Fee for service Medicare and Medicaid claims were not available. Patients were included in the claims dataset if they met HEDIS criteria for diabetes (type 1 or type 2) and were aged 18 to 75.  Each patient was attributed to a primary care provider (PCP) based on administrative data using an algorithm that has been accepted by local physicians as the basis for quality reporting. Each PCP was attributed to a practice (their "main" site if they practiced at more than one site) based on a community database that was created and maintained from a variety of sources including community partner organizations, web searches, and phone calls to practices. Diabetic patients were included in the analysis only if they could be attributed to a PCP who was in turn attributable to a specific practice from which survey data were available regarding registry use. All patient identifiers were removed before claims data were provided to the research team.

### *Measurement - Use of Diabetes Registries Meeting Meaningful Use (MU) requirements*

As discussed above, two types of registry use have been described in MU. The first MU core objective we focus on is "use clinically relevant information to identify patients who should receive reminders for preventive/follow-up care and send these patients the reminder, per patient preference." We refer to this as using a registry for "patient reminders."  The other MU core objective related to disease registry use is "generate lists of patients by specific conditions to use for quality improvement, reduction of disparities, research, or outreach." We refer to this as using a disease registry for "quality improvement." Based on answers to relevant survey questions, practices were classified as either using or not using each of these two types of registry function.

### *Measurement - Outcomes*

Quality of care for diabetic patients was measured according to HEDIS Comprehensive Diabetes Care measures, specifically lab testing (HbA1c test, LDL-C test and nephropathy screening) and dilated retinal examination (DRE). These diabetes related care are essential for optimal diabetes management and risk reduction (Statements, 2012).  For analysis, lab testing is a binary variable capturing whether or not the patients received all three types of tests, and DRE is also a binary variable indicating whether the patient have received the test.

The second group of outcome variables includes hospitalization with ambulatory care sensitive conditions (ACSC) and Emergency Department(ED) visits. These are high-cost healthcare events, many of which can be prevented with high-quality outpatient care. They are outcomes that should be sensitive to the use of registries for coordinating and improving care. ACSC hospitalizations are defined according to the Agency for Healthcare Research and Quality's Preventive Quality Indicators (PQIs) and are considered a valid measure of avoidable hospitalization (Basu et al, 2002). The numbers of avoidable hospitalizations and ED visits can be modeled as continuous variables. However, in our dataset, 97% of the patients had zero or one ACSC hospitalization and 94% of the patients had zero or one ED visit. Hence both measures were converted to binary variables to measure whether or not the patients had hospital/ED utilization.

### *Measurement - Control Variables*

We controlled for some limited patient and practice characteristics that may affect the quality of care patient received and rates of hospital utilization.  Patient-level variables include age, gender, and presence of congestive heart failure. We chose to conduct separate analyses for patients with and without congestive heart failure (CHF) because diabetics with co-morbidity such as CHF are known to have much higher rates of hospital utilization. At the practice level, we controlled for practice size using the number of diabetic patients in the practice as a proxy measure. Prior researchers have used number of patients as a measure of practice size and have found that practice size affects EHR adoption and health outcomes (Gans et al, 2005; Ketcham et al, 2007; Wang et al, 2006). We chose to use the number of diabetic patients as our measure based on the supposition that this may have a more direct effect on practice behavior with respect to diabetic patients and on our chosen outcome measures than would the total number of patients in the practice.

In order to control for patients' comorbidities, we adapted widely used Charlson Index to calculate a comorbidity score for each patient (Charlson et al, 1987). By weighting certain comorbidities, the index calculates a score that assigns a level of health to an individual. The scores are calculated using ICD-9-CM codes that used in hospitals to capture patient comorbidity information.

## Statistical Analysis

T-tests and Chi-squared tests (as appropriate) were used to compare characteristics of patients and practices between those using registries versus not using them for each of the two registry functions of interest, namely "patient reminders" and "quality improvement."  Next, in unadjusted analysis, quality of care and hospital utilization measures were compared for users and nonusers of each registry function, using chi-squared tests.

Finally, to adjust for the control variables identified earlier, we developed a regression model. Given that, in our data set, patients are nested within physician practices, Ordinary Least Squares (OLS) was not appropriate due to the hierarchical structure of data. In order to account for both patient level effects and practice level effects, we analyzed the data with a random-intercept hierarchical linear model (HLM) ( Raudenbush and Bryk, 2002), in which only the intercept of patient level model was allowed to vary and other coefficients were fixed. HLM was performed using HLM 6[1]. The Social and Behavioral Sciences Institutional Review Board at the corresponding author's home institution deemed that this work did not constitute human subjects research.

### *Results*

The necessary data were available for 12,513 diabetic patients (type 1 and type 2 combined) across 51 primary care practices. As shown in Table 1, patients in the practices that use diabetes registries for patient reminders are on average older. There is no significant difference in gender, CHF condition, type of diabetes and comorbidity score between practices using and not using diabetes registries for patient

---

[1] HLM 6 [computer program]. IL: Scientific Software International, Inc.; 2004.

reminders. Practices that use diabetes registries for quality improvement have older patients, more males, more patients with co-morbid CHF, more patients with type 2 (versus type 1) diabetes and the average comorbidity score is lower.

| | Registry NOT used for Patient Reminders (N=4775) | Registry USED for Patient Reminders (N=7738) | Test statistic (P value) | Registry NOT used for Quality Improvement (N=7370) | Registry USED for Quality Improvement (N=5143) | Test statistic (P value) |
|---|---|---|---|---|---|---|
| Age (mean) | 57.71 | 58.96 | -6.02** (p<0.01) | 58.25 | 58.81 | -2.71** (p<0.01) |
| Male Gender | 2353 (49.3%) | 3937 (50.9%) | 3.03 (p=0.08) | 3646 (49.5%) | 2644 (51.4%) | 4.56* (p<0.05) |
| Patients without CHF | 44 21 (92.6%) | 7209 (93.2%) | 1.50 (p=0.22) | 6819 (92.5%) | 4811 (93.5%) | 4.81* (p<0.05) |
| Type 2 diabetes | 4156 (87.0%) | 6652 (86.0%) | 2.88 (p=0.09) | 6304 (85.5%) | 4504 (87.6%) | 10.71** (p<0.01) |
| Comorbidity Score (mean) | 1.49 | 1.48 | 0.63 (p=0.53) | 1.51 | 1.45 | 2.97* (p<0.05) |

*=Difference significant at P<.05    **=Difference significant at p<.01

**Table 1. Comparison of characteristics of patients (type 1 and type 2 diabetes combined)**

There were 51 practices included in the analysis. Practices that use diabetes registries for patient reminders (n=36) on average have a smaller number of patients compared to other practices (t=33.67, p<0.01). Practices that use diabetes registries for quality improvement (n=24) also have fewer patients compared to other practices (t=5.77, p<0.01).

Without adjusting for any confounders, patients enrolled in practices that reported to use registries for patient reminders have higher quality of care measures on both lab tests and DRE test (p<0.01). This group of patients also have lower rate of ED visits (19.3% of patients had one or more ED visits versus 21.5%, p<0.01). Patients enrolled in practices using registries for quality improvement have a lower chance of hospitalization with an ACSC diagnosis as well as ED visit (p<0.01). These unadjusted results are presented in Table 2.

| | Registry NOT used for Patient Reminders (N=4775) | Registry USED for Patient Reminders (N=7738) | Chi Square Test Statistic (P value) | Registry NOT used for Quality Improvement (N=7370) | Registry USED for Quality Improvement (N=5143) | Chi Square Test Statistic (P value) |
|---|---|---|---|---|---|---|
| Quality of Care | | | | | | |
| Lab Testing (HbA1c, LDL, and nephropathy testing) | 3523 (73.8%) | 5987 (77.4%) | 20.88** (p<0.01) | 5567 (75.5%) | 3943 (76.7%) | 2.13 (p=0.14) |
| DRE | 2399 (50.2%) | 4183 (54.1%) | 17.26** (p<0.01) | 3872 (52.5%) | 2710 (52.7%) | 0.03 (p=0.86) |
| Hospital Utilization | | | | | | |

| Avoidable Hospitalization (ACSC) | 547 (11.5%) | 903 (11.7%) | 0.13 (p=0.71) | 920 (12.5%) | 530 (10.3%) | 14.02** (p<0.01) |
| ED visit for any diagnosis | 1028 (21.5%) | 1492 (19.3%) | 9.27** (p<0.01) | 1619 (22.0%) | 901 (17.5%) | 37.27** (p<0.01) |

*=Difference significant at P<.05    **=Difference significant at p<.01

**Table 2. Unadjusted results for quality of care and hospital utilization**


In order to take account for the effect of other factors, we included the control variables in the model. Type 2 diabetes is by far the most common type of diabetes (about 87% in our dataset) and has a different age distribution, co-morbidity pattern, and course than type 1 diabetes. Therefore, for further analyses it was decided to treat Type 1 and Type 2 separately. In this paper we present results for type 2 diabetic patients. Because diabetics with CHF are known to have much higher rates of hospital utilization, we performed separate analyses for type 2 diabetic patients with and without CHF.

| Type2 Diabetes CHF = 0 | Lab Testing | | DRE | | Avoidable Hospitalization (ACSC) | | ER visit for any diagnosis | |
|---|---|---|---|---|---|---|---|---|
| | Treatments | | | | Outcomes | | | |
| | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| Practice-level variables | | | | | | | | |
| Use registry for patient reminders^ | 1.24** | 1.12-1.36 | 1.13** | 1.04-1.24 | 0.98 | 0.83-1.16 | 0.90 | 0.81-1.01 |
| Use registry for quality improvement^ | 1.07 | 0.97-1.17 | 1.00 | 0.92-1.09 | 0.81* | 0.69-0.95 | 0.76** | 0.68-0.85 |
| Size of practice (per 100 patient) | 1.03** | 1.02-1.04 | 1.00 | 0.99-1.01 | 0.97 | 0.95-1.00 | 1.01 | 0.99-1.02 |
| Patient-level variables | | | | | | | | |
| Male Gender (vs. Female) | 1.16** | 1.06-1.27 | 0.91* | 0.83-0.98 | 1.00 | 0.85-1.17 | 0.68** | 0.61-0.75 |
| Age (per 10 years) | 1.31** | 1.25-1.36 | 1.51** | 1.45-1.57 | 0.97 | 0.90-1.05 | 0.74** | 0.70-0.77 |
| Comorbidity Score | 1.11** | 1.04-1.17 | 1.07** | 1.02-1.12 | 1.83** | 1.72-1.95 | 1.38** | 1.31-1.45 |

*=Difference significant at P<.05    **=Difference significant at p<.01

^ Meaningful use criteria

**Table 3. Adjusted results for quality of care and hospital utilization - Type 2 diabetic patients without CHF**

As shown in table 3, type 2 diabetic patients without CHF in practices using registries for patient reminders, were more likely to have laboratory tests (OR 1.24, p<0.01) and more likely to have DRE test (OR 1.13, p<0.01). There was no significant difference in terms of avoidable hospitalization and ER visit. While in practices using registries for quality improvement, patients are less likely to have avoidable hospitalizeation (OR 0.81, p<0.05) as well as less likely to have ER visits (OR 0.76, p<0.01).

Interestingly, male patients were more likely than female patients to have all three tests done but less likely to have DRE test.  Male patients were also are less likely to require an ED visit. Increasing age was associated with greater odds of completing the three lab tests (OR 1.31, p<0.01) and DRE (OR 1.51,

p<0.01) and lower odds of an ER visit (OR 0.74, p<0.01). Patients from larger practice size, as measured by number of diabetic patients, are more likely to complete all three tests. Comorbidity score which higher score indicates more comorbidity and worse health condition, was positively associated with all four measures of completing test, and hospital utilizations.

For diabetic adults with co-morbid CHF, as shown in Table 4, use of registries for patient reminders, was associated with increased odds of completing the lab testing (OR 1.63, p<0.01). Patients with CHF in practices using registries for quality improvement did not show reduced chance of avoidable hospitalization and ER visits as patients without CHF.

| Type2 Diabetes CHF = 0 | Lab Testing | | DRE | | Avoidable Hospitalization (ACSC) | | ER visit for any diagnosis | |
|---|---|---|---|---|---|---|---|---|
| | Treatments | | | | Outcomes | | | |
| | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| Practice-level variables | | | | | | | | |
| Use registry for patient reminders^ | 1.63** | 1.13-2.36 | 1.17 | 0.84-1.63 | 1.14 | 0.80-1.63 | 1.06 | 0.75-1.50 |
| Use registry for quality improvement^ | 0.95 | 0.67-1.34 | 1.17 | 0.86-1.61 | 0.95 | 0.68-1.33 | 0.72 | 0.52-1.01 |
| Size of practice (per 100 patient) | 1.05 | 0.99-1.10 | 0.97 | 0.92-1.01 | 1.02 | 0.97-1.07 | 1.03 | 0.99-1.08 |
| Patient-level variables | | | | | | | | |
| Male Gender (vs. Female) | 1.24 | 0.86-1.71 | 0.88 | 0.64-1.20 | 0.86 | 0.62-1.20 | 0.52** | 0.37-0.71 |
| Age (per 10 years) | 1.30** | 1.08-1.58 | 1.55** | 1.29-1.87 | 0.81* | 0.66-0.98 | 0.76** | 0.63-0.91 |
| Comorbidity Score | 1.04 | 0.93-1.17 | 1.08 | 0.98-1.20 | 2.05** | 1.76-2.41 | 1.25** | 1.12-1.39 |

*=Difference significant at P<.05   **=Difference significant at p<.01

**Table 4. Adjusted results for quality of care and hospital utilization- Type 2 diabetic patients with CHF**

### *Analysis of Results*

Based on the results, we developed following propositions:

Use of disease registry to send patients reminders about their tests, appointment, etc. will help patients receive the care they needed on time and improve the quality of care.

*Proposition 1: Use of disease registry for patient reminders leads to better quality of care.*

Use disease registry to track quality of care and identify the areas need to be improved will help clinics improve quality of care and lead to lower rate hospitalization and emergency room visit.

*Proposition 2: Use of disease registry for quality improvement leads to lower rate of hospital utilization.*

The impact of disease registry might vary depends on patients' conditions. The results of this study suggest that patients with less sever conditions might benefit the most from the use of registries.

*Proposition 3: The impacts of use of disease registry vary based on patients' disease seriousness and comorbidities.*

The impact of disease registry might also vary across patients in different age gourps.

*Proposition 4: The impacts of use of disease registry vary across different age groups.*

While there is no prior work in this area, the propositions we developed here could be studied to establish causality as a part of future studies – in that sense this study is exploratory in nature.

## Discussion

This study investigates the effects of 2 different uses of diabetes registries on health care and outcome for adult diabetic patients. This aligns with two MU objectives. After adjustment for patient and practice characteristics, use of diabetes registries for patient reminders and quality improvement was associated with improved care and lower acute care utilization but the effects were not homogeneous. Use of patient reminders was associated with an improved rate of laboratory testing and improved rate of DRE test for non-CHF group. Use of registries for QI was associated with reduced utilization in patients without CHF. These findings provide preliminary evidence of the value of using diabetes registry systems that align with MU objectives. They also raise interesting questions. For example, non-CHF patients in practices using reminders were more likely to complete DRE test but this was not the case for CHF patients. The reason is unclear but this finding suggests the possibility that patients without co-morbidity such as CHF may be more sensitive to reminders.

The different effect of the two types of registry use is interesting. While patient reminders seemed to positively impact compliance with testing, use of registries for QI reduces acute hospital utilization for patients without CHF. It is uncertain whether this is a direct effect of the quality improvement activities that result from using registries or is a due to an unmeasured common cause. For example, it is possible that practices that chose to use a diabetes registry for QI had a greater focus on quality of care than other practices and took greater steps to avoid acute hospital utilization than other practices. The results also indicate that patients without CHF are more likely to benefit from the use of registry. One explanation is that the treatments for patients with less severe conditions are less complicated and using disease registry can significantly improve the care they receive. It might be also easier to improve the health care outcomes of these patients.

The ongoing Beacon project is rolling out diabetes registries on a larger scale. This strategy appears to be supported by the findings of this study. Further study is needed to elucidate the benefits of registry use more definitively. This study represents an early attempt to characterize the benefits of diabetes registry use in primary care at a community level. The use of aggregated claims across the three largest payers in the community provides a more comprehensive picture that could be obtained by more traditional approaches. The ability to accurately attribute patients to practices based on intimate community knowledge is also an important strength.

There are several limitations of this study. Firstly, administrative claims data have limitations including possible misclassifications, and lack of detailed clinical and demographic information. These limitations are generally accepted as the price of access to these large datasets. The claims-based quality of care and acute care measures and the survey of registry use cover approximately the same time period. It is possible that some practices that claimed to use registries had not been using the tool for a sufficiently long period of time to see a benefit. Literature has suggested that longer usage may generate greater value, so future work is needed to explore long-term benefits of diabetes registry use. In this study, outcome measures were limited to quality of care (HEDIS) measures and certain hospitalization utilization metrics. As discussed earlier, the binary nature of the HEDIS diabetes measures may mask improvement. Alternative measures should be explored. Furthermore, future studies should consider using a broader range of outcome measures such as patient risk-factor modifications, appropriate medication use, and other patient-centered outcomes such as quality of life, and diabetes complications. Our analysis was parsimonious but perhaps overly so. We considered a very limited set of confounders in our analysis, and did not include any formal risk adjustment. In addition, registry use was based on self-report and was not independently verified.

## References

Adams WG, Mann AM, Bauchner H. (2003) Use of an electronic medical record improves the quality of urban pediatric primary care. Pediatrics. 111(3):626-632.

Basu J, Friedman B, Burstin H. (2002) Primary care, HMO enrollment, and hospitalization for ambulatory care sensitive conditions: a new approach. Medical care. 40(12):1260-1269.

Boyle JP, Thompson TJ, Gregg EW, Barker LE, Williamson DF. (2010) Projection of the year 2050 burden of diabetes in the US adult population: dynamic modeling of incidence, mortality, and prediabetes prevalence. Population health metrics. 8:29.

Bu D, Pan E, Walker J, et al. (2007) Benefits of information technology-enabled diabetes management. Diabetes care. 30(5):1137-1142.

Chaudhry B, Wang J, Wu S, et al. (2006) Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Annals of internal medicine. 144(10):742-752.

Charlson ME, Pompei P, Ales KL, Mackenzie CR. (1987) A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation* 1. Journal of chronic diseases. 40(5): 373–383.

Economic costs of diabetes in the U.S. In 2007. Diabetes care. Mar 2008;31(3):596-615.

FIDIS. (2013) Privacy by credential-based identity management. http://www.fidis.net/resources/deliverables/mobility-and-identity/int-d111000/doc/45/, 2013.

Gans D, Kralewski J, Hammons T, Dowd B. (2005) Medical groups' adoption of electronic health records and information systems. Health Affairs. 24(5):1323-1333.

Goldberg DG, Kuzel AJ. (2009) Elements of the patient-centered medical home in family practices in Virginia. Annals of family medicine. 7(4):301-308.

Harris MF, Priddin D, Ruscoe W, Infante FA, O'Toole BI. (2002) Quality of care provided by general practitioners using or not using Division-based diabetes registers. The Medical journal of Australia. 177(5):250-252.

Hillestad R, Bigelow J, Bower A, et al. (2005) Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health Aff (Millwood). 24(5):1103-1117.

Karter AJ, Parker MM, Moffet HH, et al. (2004) Missed appointments and poor glycemic control: an opportunity to identify high-risk diabetic patients. Medical care. 42(2):110-115.

Ketcham JD, Baker LC, MacIsaac D. (2007) Physician practice size and variations in treatments and outcomes: evidence from Medicare patients with AMI. Health Affairs. 26(1):195-205.

Metzger J. (2004) Using computerized registries in chronic disease care. Oakland, CA.

Maizlish NA, Herrera L. A (2005) record linkage protocol for a diabetes registry at ethnically diverse community health centers. Journal of the American Medical Informatics Association. 12(3):331-337.

Nutting PA, Miller WL, Crabtree BF, Jaen CR, Stewart EE, Stange KC. (2009) Initial lessons from the first national demonstration project on practice transformation to a patient-centered medical home. Annals of family medicine. 7(3):254-260.

Ortiz DD. (2006) Using a simple patient registry to improve your chronic disease care. Family practice management. 13(4):47-48, 51-42.

Raudenbush SW, Bryk AS. (2002) Hierarchical Linear Models: Application and Data Analysis. Thousand Oaks, Newbury Park, CA: Sage.

Raudenbush SW, Bryk AS. (2002) Hierarchical Linear Models: Application and Data Analysis. Thousand Oaks, Newbury Park, CA: Sage.

Renders CM, Valk GD, Griffin SJ, Wagner EH, Eijk Van JT, Assendelft WJ. (2001) Interventions to improve the management of diabetes in primary care, outpatient, and community settings: a systematic review. Diabetes care. 24(10):1821-1833.

Stroebel RJ, Scheitel SM, Fitz JS, et al. (2002) A randomized trial of three diabetes registry implementation strategies in a community internal medicine practice. The Joint Commission journal on quality improvement. 28(8):441-450.

Statements P. (2012) Standards of medical care in diabetes—2012. Diabetes care. 35(supplement 1):S11-S63.

Schmittdiel J, Bodenheimer T, Solomon NA, Gillies RR, Shortell SM. (2005) Brief report: The prevalence and use of chronic disease registries in physician organizations. A national survey. Journal of general internal medicine. 20(9):855-858.

Wang Y, O'Donnell CA, Mackay DF, Watt GC. (2006) Practice size and quality attainment under the new GMS contract: a cross-sectional analysis. The British Journal of General Practice. 56(532):830.

Wang SJ, Middleton B, Prosser LA, et al. (2003) A cost-benefit analysis of electronic medical records in primary care. The American journal of medicine. 114(5):397-403.

Young AS, Chaney E, Shoai R, et al. (2007) Information technology to support improved care for chronic illness. Journal of general internal medicine. 22 Suppl 3:425-430.