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Impact of an Electronic Medical Record on Adherence to Current Diabetes Guidelines in a Family Medicine Center

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IMPACT OF AN ELECTRONIC MEDICAL RECORD ON ADHERENCE TO CURRENT DIABETES GUIDELINES IN A FAMILY MEDICINE CENTER

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A DISSERTATION

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ADMINSTRATIVE-HEALTH SERVICES PHD

ABSTRACT

OBJECTIVE: Extensive research shows that diabetic care often falls below recommended guidelines. Many believe that Electronic Medical Records (EMR) have the ability to improve quality of care. The primary goal of this study is to evaluate the changes in diabetic care and outcomes pre and post EMR implementation.

RESEARCH DESIGN AND METHODS: The study took place at the UAB Huntsville Family Medicine Center. A retrospective chart review was conducted in order to determine the impact of an EMR on diabetes care. This is a natural experiment that uses a pre post model in order to determine impact. Generalized Estimating Equations were used to determine the changes in diabetic care and outcomes pre and post EMR implementation.

RESULTS: Order rates for all three tests investigated increased after implementation of the EMR however only the increase in microalbumin orders was statistically significant. Microalbumin tests were 147% more likely to be ordered post EMR implementation and the difference was significant ($p<.001$). HbA1c tests were 26% more likely to be ordered

post EMR implementation and LDL tests were 18% more likely to be ordered post EMR but the differences were not statistically significant. The HbA1c was 1% less likely to be performed and the LDL was 11% less likely to be performed post EMR but neither difference was statistically significant. Microalbumin tests were 98% more likely to be performed post EMR implementation and the difference was significant ($p<0.001$).

The EMR was associated with an improvement in microalbumin, HbA1c, and LDL control. Patients seen after EMR implementation were 20% more likely to have an HbA1c <7 ($p=0.033$), 34% more likely to have a LDL<100 ($p<0.001$), and 55% more likely to have a microalbumin<20 ($p<0.001$).

CONCLUSIONS: Patterns of care did change after EMR implementation. EMRs may improve quality of care but it is unclear what tools in the EMR may contribute the change.

DEDICATION

This work is inspired by my family and friends that have always supported me. Thank you Heather for the sacrifices you made to allow me to achieve one of my life goals.

Thank you Lilli for showing me what is important in life. Thank you, Sadie, for your great sense of timing.

Thank you to my parents for giving me all the support and help I needed to reach my goals. Thank you J, Bob, Susan, and Maya for the positive energy you give me. Liam you have inspired me and made this research more personal which increased my desire to work on it.

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Gerald Glandon, Jeroan Allison, Dow Briggs, Gary Cutter, and Meredith Kilgore all were all great to work with and provided their unique insights to improve the project.

I would like to thank everyone at the UAB-Huntsville campus where I conducted this research. The implementation of the EMR was tough on everyone at first but now everything seems to be running smoothly. Without their hard work none of this would have been possible. In particular I would like to thank Robert Centor for giving me the opportunity to come and work at the UAB Huntsville Campus.

Thanks to you Martha Hilley for making sure I always knew what steps to take. Without you I am sure I would have missed something.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table *Page*

LIST OF FIGURES

Figure *Page*

LIST OF ABREVIATIONS

AR(1)	First order auto regression
CAD	Coronary artery disease
CCHIT	Certification Commission for Healthcare Information Technology
COPD	Chronic obstructive pulmonary disease
CVD	Cardiovascular disease
DCCT	The Diabetes Control and Complications Trial
DPN	Distal symmetric polyneuropathy
DSME	Diabetic self monitoring education
EMR	Electronic Medical Record
GEE	Generalized estimating equations
HbA1c	Hemoglobin A1c
HDL	High-density lipoprotein
HMP	Health maintenance plan
HPI	History of present illness
IOM	Institute of Medicine
LDL	low-density lipoprotein
PCP	Primary care provider
ROS	Review of systems
SMBG	Self monitoring blood glucose
UASoMH	University of Alabama at Birmingham Huntsville Campus

CHAPTER 1— INTRODUCTION

In 1996 the Institute of Medicine (IOM) began an effort to improve the quality of health care in the United States. As part of this effort the IOM has released multiple publications addressing the mechanisms that could be used to enhance the quality of care. (1). In 1999 the IOM released “To Err is Human: Building a Safer Health System”. This report discussed a strategy to improve the quality of health care in particular by preventing errors (2). A second report “Crossing the Quality Chasm: A New Health System for the 21st Century” was released that offered more direction to health care entities about how to improve quality. In this report the Institute of Medicine suggested that adoption of health information technology will be essential to improving the quality of health care services over the next decade (3).

In addressing the needs for improved quality of health care the IOM has established a set of key capabilities for electronic medical records (EMR) that has the potential to improve the efficiency and quality of healthcare in the United States. All EMR systems are to include longitudinal patient data, offer immediate access by authorized users, provide knowledge and decision support, and support efficient processes of health care delivery. These requirements where developed in order to improve patient safety, support the delivery of effective patient care, facilitate the

management of chronic conditions, improve efficiency, and to allow feasible implementation (4).

The IOM guidelines are pushing the medical profession to adopt EMRs. The medical profession lags behind other industries in the use of information technology systems to enhance performance. However, EMRs are gradually being adopted. Approximately 24% of ambulatory care physicians used EMRs in 2005 (5), this is up from an estimated 17% of office based physicians in 2003 (6). If the adoption rates of EMRs follow the patterns seen with other technological innovations a substantial increase in adoption is likely to be on the horizon. It is posited that the majority of the market develops only after a significant portion of peers in a community have adopted a product and is considered a reference group on which product success or usefulness can be evaluated (7). With an estimated 24% of ambulatory care physicians using EMRs, it is likely that most physicians not using EMRs at least know one who is using an EMR. The availability of peer references should drive further increase in adoption rates. With the current and potential use of EMRs, one must consider what impact the EMRs will have on healthcare.

EMRs have the potential to increase the efficiency and effectiveness with which health care is provided. However, the benefits of EMRs are still unclear. Other industries have seen up to 4% per year gains in productivity due to information technology. An increase of this magnitude could reduce healthcare spending by billions per year (8). The potential cost reductions are impressive but the true impact of the EMR lies with its

ability to improve the quality of care that is given to the patient. Many EMR systems are equipped with decision support tools that give the provider reminders and cues about the needs of a particular patient. These decision support tools combined with easily accessible patient data have the potential to improve the quality of care for patients.

The primary goal of this study is to evaluate the changes in diabetic care and outcomes pre and post EMR implementation. The best way to measure the changes in patterns of care is to consider prior measures of high quality care. Quality of care is a nebulous concept but the most concrete measures come from the evidence based treatment guidelines that have been developed. Well developed decision support tools should prompt providers to follow evidence-based treatment guidelines. This should improve the quality of care across the board and reduce practice variation.

Practice variation has been well documented. Early investigations into variations in health care focused on surgical procedures. In 1938 Glover investigated the incidence of tonsillectomy (9) and since then several studies have shown that physician practice variation does occur (10-13). Current efforts to understand variations in health care outcomes have extended this research to look at variations in chronic disease by measuring patient outcomes. In particular, a large body of research has focused on the variation in treatment of diabetes mellitus which is covered in the literature review.

Diabetes Mellitus is one of the most commonly occurring chronic diseases in the United States. Diabetes is characterized by an inability to produce insulin in type 1

diabetics or an inability of the body to be able to properly use insulin in type 2 diabetics. Insulin is a hormone that regulates the amount of sugar that is stored in the blood. Diabetes is likely caused by a mixture of genetic and environmental factors although the exact cause remains a mystery (14).

Diabetes is typically diagnosed based on the results of a glucose test. A person is considered to be diabetic if their fasting glucose is above 126 mg/dl or if the two-hour blood glucose level is at 200 mg/dl or higher. Increased glucose levels can lead to a myriad of medical complications (14).

According to the National Institute of Diabetes and Digestive and Kidney Diseases, over 18 million people in the United States are diabetic. Diabetes is the sixth leading cause of death amongst diseases in the US. In 2002, the total cost of diabetes in the US was estimated to be $132 billion (15). The costs and deaths associated with diabetes are expected to grow in the future. Death from diabetes is becoming more prevalent (16). The rates of diabetes are expected to grow and males born in 2000 are estimated to have a 32% lifetime chance to develop diabetes while females born in 2000 are estimated to have 38.5% chance to develop diabetes (17). Diabetes can lead to heart disease, stroke, blindness, kidney failure, pregnancy complications, lower-extremity amputations, and deaths related to flu and pneumonia (15).

Diabetes offers an excellent setting in which to study the impact of the EMR on patterns of care due to the high prevalence of diabetes and the body of work already

completed about monitoring and care for the disease. Established diabetes treatment guidelines are in place and extensive research has been done concerning quality of diabetic care. This study is designed based on the Donabedian structure, process, outcomes paradigm (18). Donabedian believed that both structure and process had an effect on health outcomes and that measuring outcomes was the proper way to evaluate a process.

Structure is "the relatively stable characteristics of the providers of care, of the tools and resources they have at their disposal, and of the physical and organizational settings in which they work" (18). The structural level variables of interest in this study are patient and physician demographics. Structure level variables set boundaries that limit process possibilities.

The process involved is patient-physician interaction, as shown in Figure 1. This study should lend evidence as to how one can best change the process in order to improve outcomes. Variables associated with this interaction include treatment regimen and patient compliance.

Donabedian defines outcomes as "a change in a patient's current and future health status that can be attributed to antecedent health care" (18). This study is designed to look at the process of care as well as intermediate outcomes. The primary goal of this study is to evaluate the changes in diabetic care and outcomes pre and post EMR implementation.

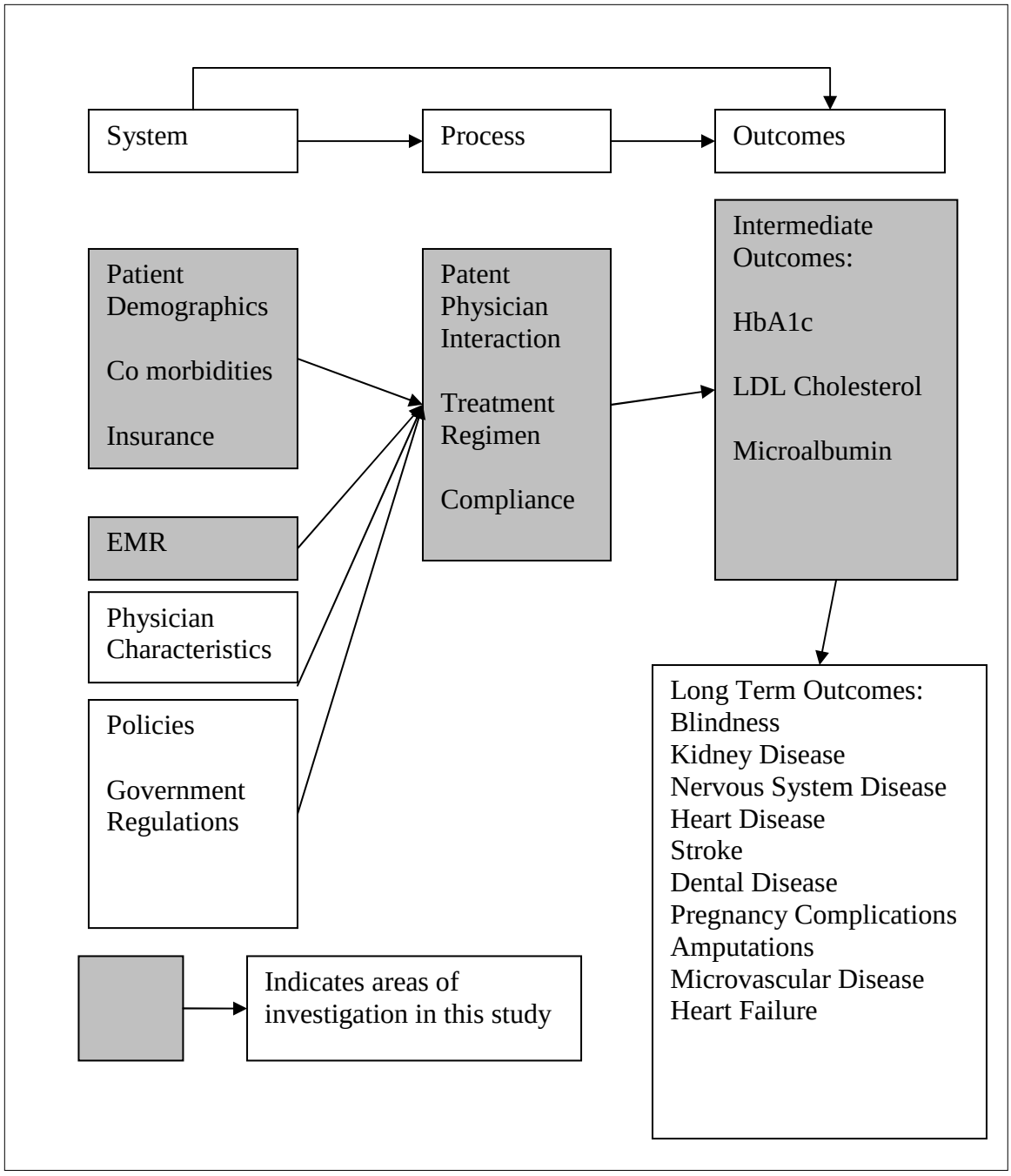


Figure 1. Donabedian Paradigm

CHAPTER 2—LITERATURE REVIEW

This chapter will cover the treatment guidelines, show the current state of diabetes care, and explore different methods that have been used to improve diabetes care. The factors that impact diabetes management and the programs that aim to improve the quality of diabetic care have been studied to great extent. The issue of diabetes management is extremely complex. The treatment guidelines and numerous patient, physician, and environmental factors that impact diabetes confuse the issue. In light of this, many programs have been designed to improve diabetes care. These programs include interventions that have used EMR's, and these typically are evaluated based on adherence to diabetes guidelines. These diabetes guidelines are built on an established evidence base that shows the benefit of following them (15). This chapter is split into eight sections. The first four sections - Glycemic Control & Monitoring, Lifestyle, Management of Co morbidities, and Screening – discuss diabetes guidelines and their importance.

The Quality of Care section discusses past research that has shown that treatment of diabetes is often below guidelines. The Quality Drivers section discusses the reasons why the level of care is falling below the standards set in the guidelines. The How to Improve Care section covers numerous ways to improve quality of care. The final section

includes a review of prior studies that considered the impact of Electronic Medical Records on diabetes patterns of care.

Glycemic Control & Monitoring

Glucose monitoring is essential to diabetes management and can be done using various methods. Blood glucose tests can be used to monitor short term sugar levels while the HbA1c gives an average glucose level over the past two to three months (19).

Self-monitoring of blood glucose is recommended (SMBG) and is considered useful in order to maintain a frequent watch on glucose levels (15, 20, 21).

Hemoglobin A1c (HbA1c) tests should be performed two or more times a year depending on disease state. This test is useful because it gives a weighted average of a patient's glucose level over the past 2-3 months (15, 22). HbA1c is often used in order to determine proper treatment (15). Conducting both SMBG and HbA1c is important so that the patient and provider can understand what is needed to maintain glycemic control.

Generally the target HbA1c for patients is 7% which correlates to a glucose level of 170 mg/dl (15, 23). Several trials have shown that better glycemic control is negatively associated with retinopathy, nephropathy, and neuropathy (24-27). Lower HbA1c values have also been linked to a decrease in microvascular events (28-29).

Lifestyle

Lifestyle modifications are the first line of therapy for many diabetics. Lifestyle modifications include a variety of educational and behavioral interventions that are discussed below. All diabetics should get medical nutritional therapy in order to reach their treatment goals. This therapy includes controlling their weight as well as consuming a proper mix of foods.

All diabetics should receive diabetic self monitoring education (DSME). DSME can lead to improved health outcomes (30-35).

The guidelines also recommend physical activity in order to improve glycemic control, weight control, and reduce risk of cardiovascular disease (15).

Psychological and social assessment of diabetics is recommended because it can allow physicians to know about a patient's ability to partake in self care (15, 36-41).

Flu shots should be given annually to all diabetics. Flu shots have been shown to greatly reduce the hospital admission rates of diabetics during flu epidemics (15, 42).

Management of Co Morbidities

The majority of diabetics are hypertensive which increases the risk of vascular complications (15). Blood pressure should be measured at all diabetic visits. Systolic blood pressure should be below 130 mmHg and diastolic should be below 80 mmHg. The

benefits of controlling blood pressure in diabetics have been shown in several studies (15, 43-46) Blood pressure control has been linked to fewer cardiovascular events and lower mortality (15, 43, 47-48).

Cholesterol levels should be measured annually. LDL cholesterol should be below 100 mg/dl, HDL should be above 40 mg/dl, and triglycerides should be below 150 mg/dl (15). Prevalence of dyslipidemia is high among diabetics and several studies have shown that controlling lipid levels can lower cardiovascular risk (49-58).

Maintaining blood pressure and cholesterol control is essential to limiting the risk of cardiovascular disease (CVD). Hypertension and dyslipidemia are both risk factors for CVD (Guidelines 59-63). Diabetics are 2 to 3 times as likely as non-diabetics to suffer from CVD (64-65).

Screening

The combination of a microalbuminuria and a serum creatinine level can be used to monitor for kidney disease. Nephropathy screening should occur annually by completing these two tests. Diabetes is one of the leading causes of kidney disease (66). Diabetes accounts for 44 percent of new cases of end-stage renal disease (15). Current guidelines recommend glucose and blood pressure control in order to limit the risk of kidney disease.

Diabetes is the leading cause of adult blindness with diabetic retinopathy causing 12,000 to 24,000 cases of blindness each year in the US (15). Patients that tightly control their HbA1c will have fewer incidences of microvascular complications including diabetic retinopathy (67-70). The Diabetes Control and Complications Study found that strict control of blood glucose reduced mean risk of retinopathy by 76 percent (68). Glycemic and blood pressure control can lower the risk of diabetic retinopathy. Current guidelines recommend that diabetics have a dilated eye exam shortly after diagnoses of diabetes. Annual eye exams are recommended after the initial exam. (15)

Mild or severe nervous system damage occurs in 60 percent to 70 percent of people with diabetes. Nervous system damage can result in impaired sensation or pain in the feet or hands, slowed digestion of food in the stomach, carpal tunnel syndrome, and other nerve problems. Over 60 percent of non-traumatic lower-limb amputations occur among people with diabetes (15). The Diabetes Control and Complications Trial (DCCT) found that glycemic control can delay the progression of diabetic neuropathy (69). It is recommended that all diabetics be screened for distal symmetric polyneuropathy (DPN) annually. Foot inspection to screen for neuropathy should be performed every 3 to 6 months. (15)

Quality of Care

Despite the evidence of the benefits of the guidelines recommended several studies have found that diabetes treatment falls short of recommended guidelines (15, 71-80). This is no doubt due in part to the large amount of testing and daily self management that is required by diabetics. The guidelines themselves call upon the patient and physician to complete many tasks but also require that certain services such as diabetic education are available.

Many diabetics do not follow recommended preventive measures. In 1998 researchers found that many patients did not conduct self monitoring blood glucose checks, get HbA1c tests, receive foot inspections, or have dilated eye exams as recommended (76).

More recent studies have found that the quality of diabetes care is improving but further improvement is still needed (72, 74). Saadine et al. found that intermediate diabetes outcomes including LDL cholesterol, blood pressure, and glucose levels were not well controlled for a large portion of diabetics (74). Jencks et al. found that a large proportion of diabetics are not getting the proper care they need. They found that many patients do not have HbA1c tests, eye exams, or lipid profiles done on a regular basis (72).

Quality Drivers

A number of studies have attempted to the sources of variation in glycemic control. The previous studies have looked at numerous patient, physician, and practice level factors. At the patient level age has shown to have a positive impact with glycemic control. Results suggest that patients learn to manage diabetes better as they get older and that only the lives of the well managed are extended (81-84). Treatment regimen, which considers if patients should use oral medication, insulin, diet and exercise, or a combination thereof, also is an important factor. Diabetes is a progressive disease and typically those on no drugs do the best followed by those on oral medications, and then those using insulin. Typically only the type II diabetic patients that have not improved their condition with diet and exercise will be given anti-diabetic medications (83, 85-91). Studies disagree over the impact of gender (82, 85, 87). Caucasians tend to have better diabetes management than other racial groups (82, 87, 88, 92, 93). Patients that have been more recently diagnosed tend to have better diabetes control (81, 85). People of higher socio economic status tend to have better diabetes control (82, 84, 93, 94-96). Patients with more limited insurance had worse diabetes management (82, 96, 97). The more comorbidities a patient has the poorer their diabetes management tends to be (84-87, 93, 98). Non-compliance with treatment has also has a negative impact on diabetes management (92, 93, 98-101).

Mixed evidence has been given on the association of physician and clinic level variables with HbA1c (81, 85, 95, 97, 99, 102-104).

At the practice level, better equipped practices (85), larger practices (85, 95, 97),existence of a diabetic mini-clinic (85), access to a dietician, or a practice nurse skilled in diabetic care (85), and longer appointments (95) have all been linked with better diabetes control

Few studies have looked at patient, physician, and practice level variables at the same time. Krein et al. conducted such a study to evaluate the variation in diabetes practice patterns and the reliability of diabetes care profiles. The study considered variables attributable to the primary care provider (PCP), the physician group, and the facility. “The greatest amount of variance tended to be attributable to the facility level” (104). Process level measures had up to 9% of their variance attributed to the PCP, however, intermediate level outcomes did not have a large amount of variance attributable to the PCP. In particular only 1% of the variation in most recent HbA1c values was attributable to the PCP. None of the variance in HbA1c was attributable to the provider group but 12% of the variance in HbA1c was attributable to the facility level (103). This study did use patient case-mix adjustments; however patient variables were not the emphasis.

Based on the evidence, patient factors play an important role on diabetes control, as do practice level factors. The physician level factors tended not to be significant in most of the studies in which they were considered.

How to Improve Care

Programs of numerous shapes and sizes designed to improve diabetes care have been implemented and studied with varying results.

Many quality improvement projects have been studied. While most show some improvement in process level measures, few disease management programs are able to show changes in intermediate diabetic outcomes. These results are in congruence with the research that showed that physician factors have little impact on glycemic control. The results of a study by Mangione et al. that evaluated multiple diabetes quality improvement programs exemplify this. It found that three quality improvement strategies increased retinal screening, nephropathy screening, foot exams, and HbA1c blood tests. The three strategies were performance feedback, physician reminders, and diabetes care management. However, none of the strategies were associated with improvements in HbA1c, blood pressure, or LDL cholesterol (105).

Research using in-depth interviews of 19 primary care physicians offered some insight into how to improve diabetes care. Although physicians had goals that were in line with guidelines they found that patient issues often made proper management of diabetes difficult. The study concluded that diabetic care should be tailored to meet the needs of individual patients and that physicians need to improve their motivational counseling skills. They also suggest that office systems be designed to support patient adherence (99).

Case management programs that actually involve an increased number of visits tend to be more successful at improving intermediate diabetic outcomes such as HbA1c.

In the past, disease management programs that aim to modify physician behavior and case management programs that modify the amount of care that patients receive as well as many other types of interventions have shown that they can improve the quality of diabetic care. This literature has also extended to show benefits from electronic medical record systems.

Prior EMR Studies

Studies that have focused on the impact of electronic systems on quality of care have had shown that EMRs and other electronic systems have similar impacts to other quality improvement initiatives. EMRs and electronic prompting systems have been linked with increase rates of foot exams (106), eye exams (106), health maintenance (107), recommended care (108), improved clinical practice (109), quality of care (110), HbA1c (111), LDL (111), frequency of HbA1c (112), and frequency of LDL (112). However, some studies found that EMRs have no impact on quality of care (113).

Two studies were found that looked specifically at the impact of an EMR on the quality of diabetic care provided. O'Conner et al. conducted a study to look at the impact of an EMR implementation on diabetes quality of care. The EMR that was used for the study was developed by Epic Systems. Initially the system provided prompts to physicians when diabetic patients were due for an Hba1c or microalbumin tests. A year

after implementation prompts were put in place to create reminders about blood pressure checks, cholesterol labs, and aspirin therapy. The prompts were on screen but they did not require a response. The study took place in two clinics. One implemented an EMR and the other did not. A total of 122 patients were followed for 5 years. The clinic that implemented the EMR followed 57 while the control clinic followed 65. Both clinics had 4-5 physicians and did not have residency training duties. The two clinics were similar at baseline (114).

The measure of quality was the number of labs that were completed. The study found that EMR increased the number of HbA1c and cholesterol tests but they did not see an impact on actual HbA1c or cholesterol levels. The study looked only at labs performed; it did not look at labs ordered. The EMR should prompt the physician to order more tests even if the orders are not always followed. The study also looked at only a small subset of the diabetes guidelines because the EMR was only expected to have an impact on a few items. It also measured the impact of looking at the number of labs performed which may or may not be the result of a physician following guidelines and ordering the tests more often.

Welch et al. used a natural experiment to study the impact of an EMR on cost and quality of care. The study examined the implementation of EMRs in 4 clinics. A control group of 52 clinics that did not have EMRs was also assessed. The study used claims data to assess the impact of the EMR on cost and quality of care for patients with diabetes, hyperlipidemia, heart conditions, hypertension, or any combination of these diseases. The

clinics had differing EMRs with differing functionality. One clinic did not have a full EMR but instead had an enhanced practice management system and access to results from the hospital (113).

In order to measure quality, the study only measured guidelines that the physician could be held accountable for. The study found that the EMR had no impact on cost, quality of diabetes care, and quality of care for heart conditions. EMR implementation was associated with higher quality of care for hyperlipidemia and hypertension. The study used an algorithm to determine if total diabetic care had improved in quality. It did not report the significance of the changes in the individual diabetes quality indicators (113).

The study has several weaknesses. First, the experimental group was not all using the same EMR. It is also not clear if all the physicians at those practices were using the EMR or to what extent. The systems in two of the experimental clinics had EMRs with diagnostic data, lab work, imaging, e-prescribing, and some decision support. The third experimental clinic had similar functions except it did not have imaging. The fourth experimental clinic did not have an EMR and should not have been included. It was included because it did have limited e-prescribing and access to the local hospital system. It is quite possible that control clinics also had the same capabilities as the fourth experimental clinic.

The systems were rolled out at the experimental clinics so it is unclear when or if the different functionalities came into effect.

The study used claims data that may give a skewed view of guideline adherence that also is impacted by patient compliance. Many patients are non-compliant so even if a physician has ordered the lab work that is needed it may not be completed by the patient. This will look like a failure of the physician. This is unreasonable because the study targeted only guidelines that the physician could reasonably control.

Intent of study

This study builds on the existing literature in order to analyze the changes in diabetic care and outcomes pre and post implementation of Allscripts Touchworks version 10.2 EMR. This study differs from prior studies because it looks at a large range of diabetic quality of care indicators as well as diabetic intermediate outcomes. The data comes directly from the medical record which allows us to look at the information in three ways. We are able to measure changes in what the physician has ordered as well as changes in what labs the patients actually completed and finally we are able to measure the intermediate diabetes outcomes themselves. This study offers insight into how EMRs are already improving care and what areas need to be improved.

CHAPTER 3—METHODS

Setting

In August of 2006 the University of Alabama School of Medicine Huntsville Regional Medical Campus (UASoMH) installed the Allscripts Touchworks version 10.2 EMR. The event offers an opportunity to study patterns of care before and after the installation of the EMR. The study was approved by the University of Alabama at Birmingham Institutional Review Board.

The UASoMH was established in 1973 and in the past 30 years has emerged as the medical education leader in the northern part of the state as well as an advocate for enhancing family-oriented healthcare delivery for Huntsville and the surrounding non-urban communities. It is the premier center for the training of family physicians, education of medical students, and for supplying high quality healthcare to North Alabama families. Besides providing medical care to over 100,000 patients per year, the UASoMH has trained about one-third of Alabama's primary care physicians. Since 1976, the Huntsville Regional Medical Campus has trained 352 medical students who chose careers in primary care; 35 percent of these physicians now practice in rural areas. In Alabama today, there are close to 100 practicing family medicine physicians who graduated from the campus' residency program.

The study itself will focus on the Family Medicine Clinic at the UASoMH. The clinic has nine attending physicians and thirty-six residents. Approximately 110 patients a day are seen by physicians. The clinic also has two pharmacists that provide drug and disease management education.

The EMR was rolled out to the family medicine clinic in a single event on August 16, 2006. The system is used by everyone at the clinic. After the system was installed, no more data was collected on paper. All clinical documentation is done in the EMR in one of a variety of modules. Below is a list of the modules in use at the clinic and their capabilities.

Workflow

The EMR is broken into nine integrated modules. In order to describe how the EMR works and changes the way physicians practice, an example workflow for a typical patient will be given as well as a description of the functions of the various modules. All patient information presented in screenshots is from hypothetical test patients.

The bulk of the visit is documented in the note module which replaces the traditional paper note. Notes can be built in two ways. One option is to create text templates, which incorporate templates with the ability to add free text. This is commonly used when users are discussing the history of the present illness (HPI). The system also uses Medcin templates which allow the user to simply click on problems that are present or absent. The system at UASoMH is designed with multiple diabetes-specific templates.

These templates are used in most sections of the note. Medications, orders, results, allergies, and other items that are in the other parts of the system can all be documented in the note with the click of a button. The clinic does not do any dictation.

The clinical portion of the visit begins with the nurse taking the patient's vital signs and entering any patient history that has been reported. The nurse may add an active problem and place an order for in-house test if needed. The nurse will also enter the chief complaint of the patient. An example of the vitals intake form in Figure 2. Data that is generated on the vitals screen will automatically be pushed to the note created during the patient visit.

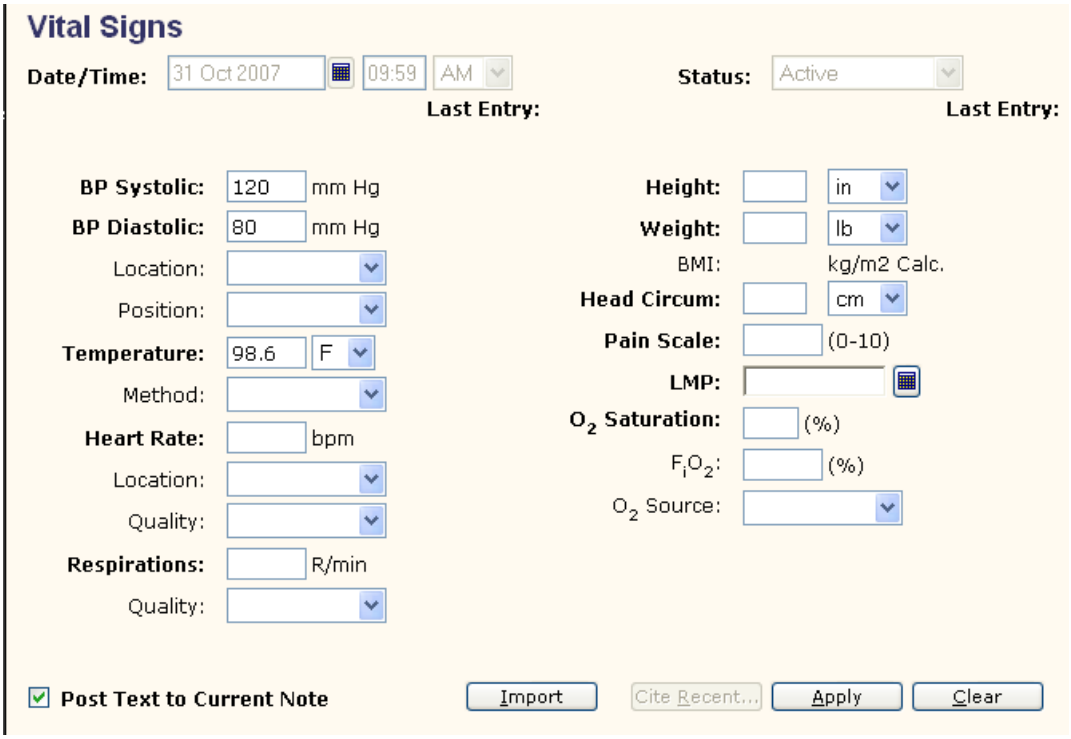


Figure 2. The vitals entry screen.

Before seeing the patient, the physician will review prior visits, look at lab results, and review documented medications and problems. This is typically done by looking at the ChartViewer and SnapShot sections. The physician will look at the patients chart beginning with a “SnapShot” of the patient. Here the physician is able to see what medications a patient is taking and what problems they have. They can also see if they have any labs that need to be ordered as well as a history of past patient visits and a list of tasks that are associated with the patient. The SnapShot screen presented in Figure 3 is the first page that physicians see when they go to a patient during a typical visit workflow.

The next page that is often reviewed is the ChartViewer. Here a physician can look at all the notes, test results, and correspondence about the patient. This page also will identify any tests that have not yet been reviewed by the provider. A screenshot of the ChartViewer is in Figure 4. The ChartViewer allows users to quickly review all documentation available on a patient, however, no data can be added while in the ChartViewer.

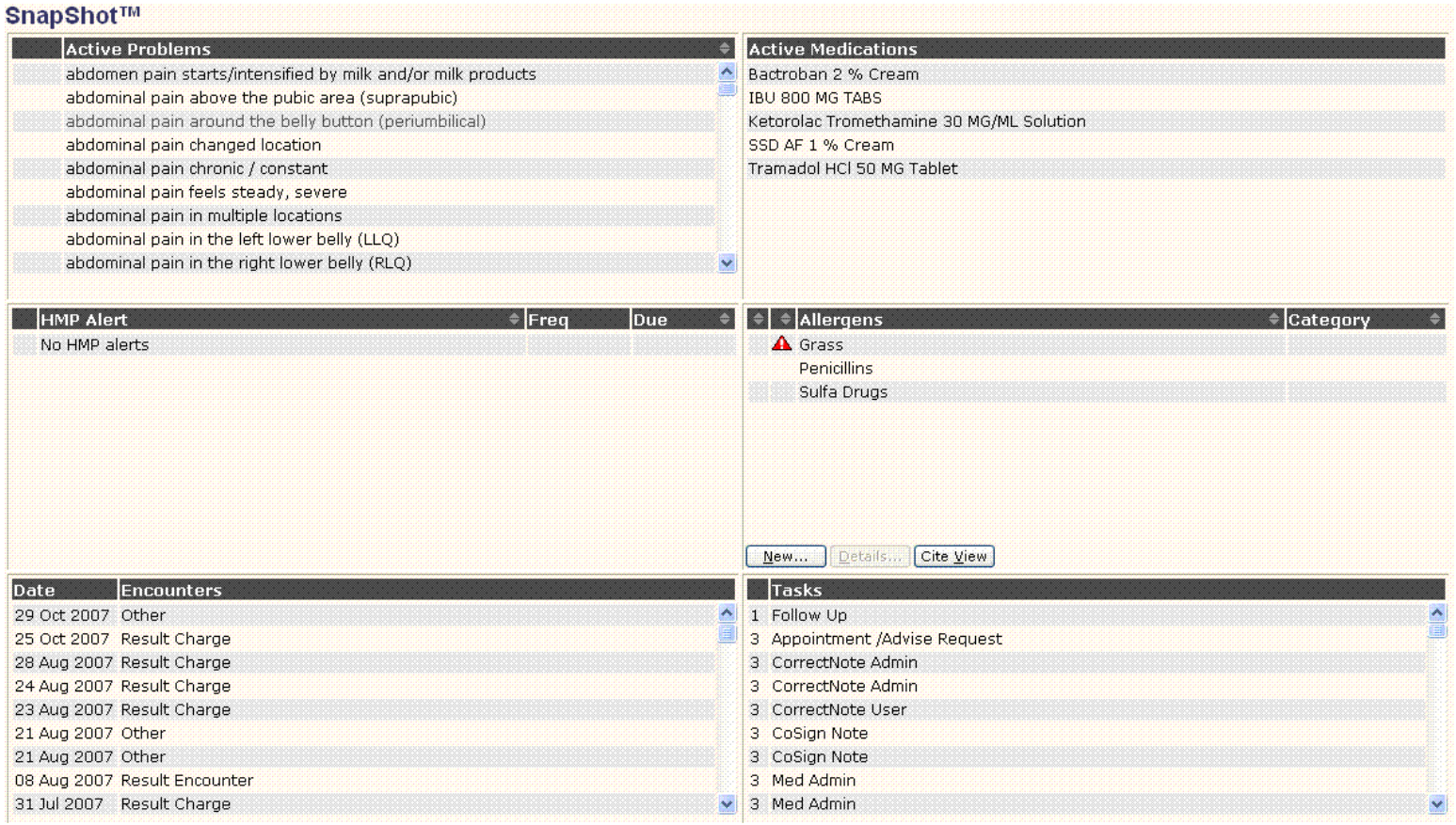


Figure 3. SnapShot offers a quick view of a patient's problems, medications, health maintenance plan alerts, allergies, tasks, and encounters.

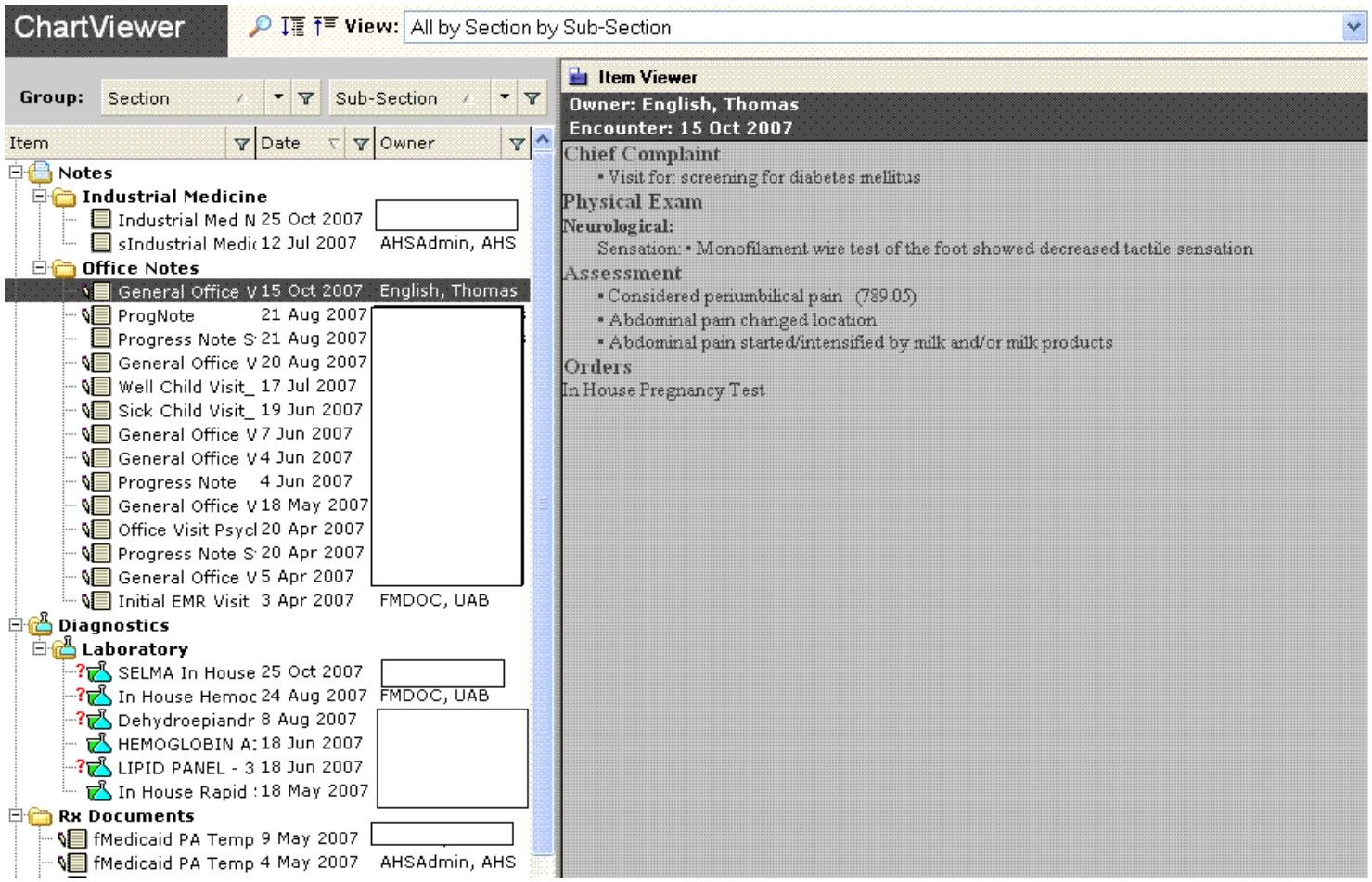


Figure 4. ChartViewer displays all notes, labs, correspondence, and encounters for the patient.

The physician will begin the visit by reviewing the chief complaint and documenting the HPI. Documenting in the chart is driven by templates however physicians do have the option of entering free text. Although physician created templates are available for most common diseases many providers prefer to write an unstructured HPI. Figure 5 shows the diabetes HPI template.

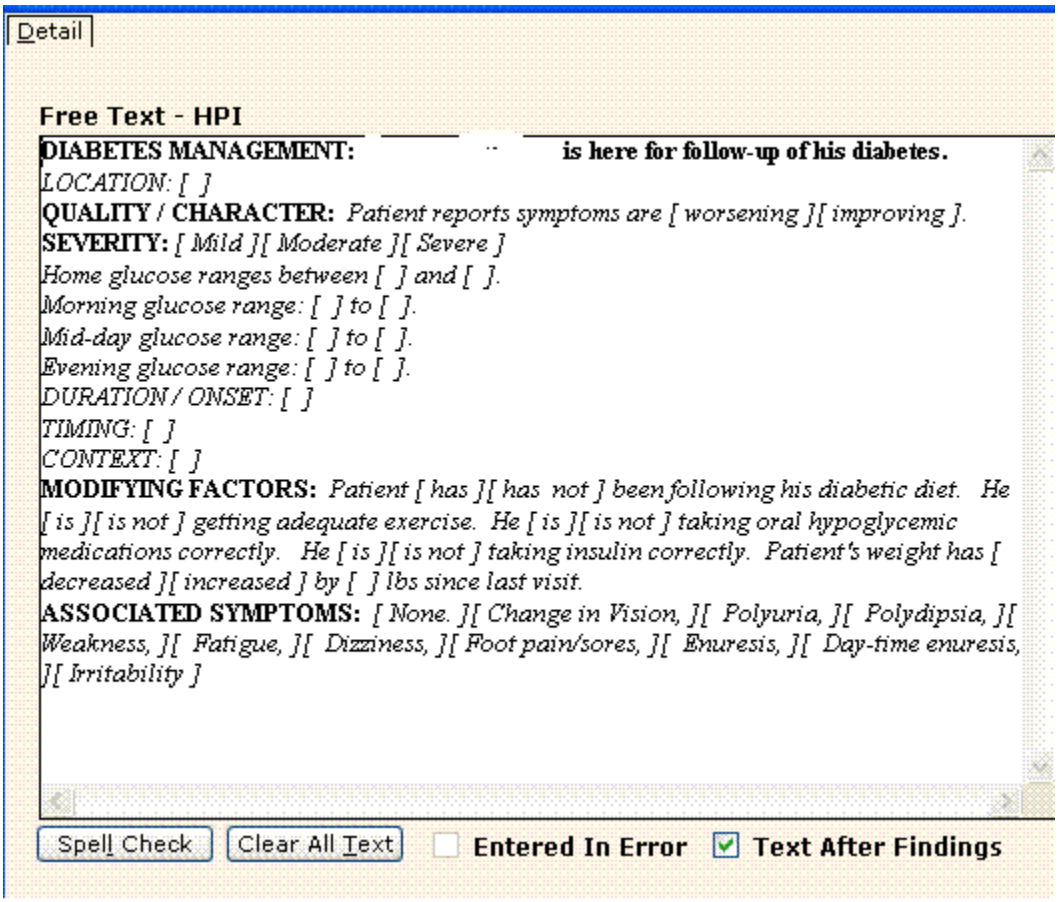


Figure 5. Text template for diabetes HPI

Next, the physician will document any chronic active problem. This can be done using the search function in the note or in the problems list. Items in the problem list can be cited to the note at anytime, so if diabetes is diagnosed at an initial visit it can be cited from the problem list in follow-up visits. The physician can then review the patient's personal history, past medical history, family history, and past surgical history. The historical items typically are entered by the nurse and the doctor can cite them into the note at anytime.

The physician will now document the review of systems (ROS) and the physical exam. These will both be documented in a manner similar to the HPI. Figure 6 shows an example of the diabetes templates for the physical exam section.

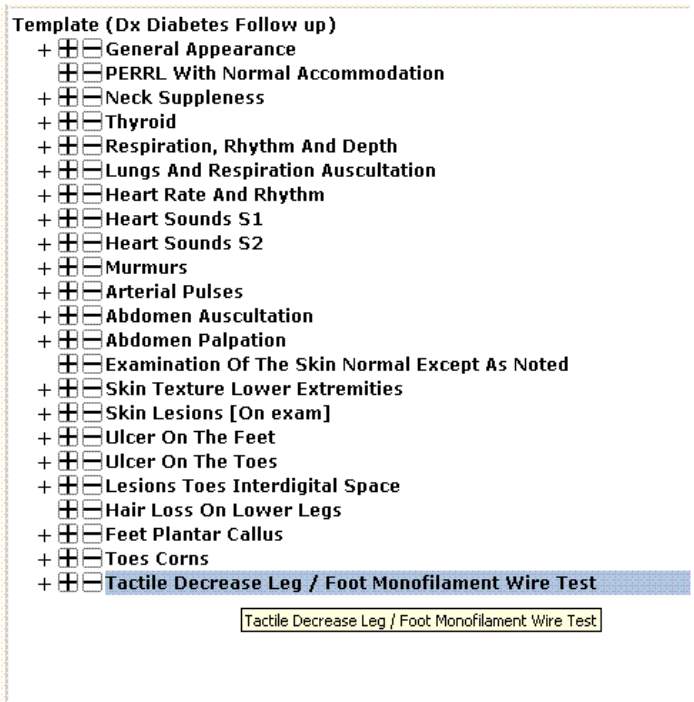
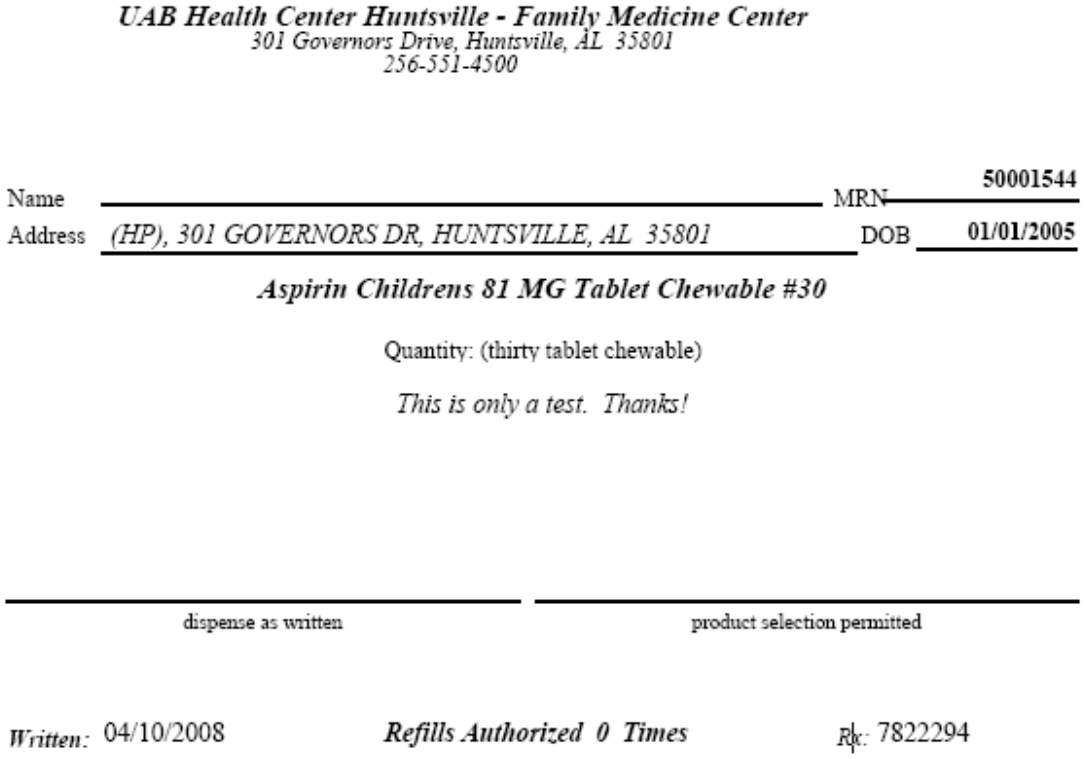


Figure 6. Diabetes physical exam template

The physician will now cite any important results to the note and document the assessment. Results can be cited in quickly from within the note or by going to the results view. The physician can assess problems by going to the active problems page using the assess button.

Now the physician can place orders for testing and medication. Prescriptions are made in the New Rx workspace in the Rx+ module. The Rx+ module is used to create and send prescriptions electronically. All medication information is created and stored in the system. This allows the clinic to send prescriptions to pharmacies online while still having the option to fax or print prescriptions if necessary. Some drugs require a written script in Alabama and some local pharmacies do not have the systems in place to receive electronic prescriptions so the system was built to be flexible. This module will notify physicians if the drug is not a preferred drug based on patients' insurance. The module also interacts with patients' allergies in order to determine if a medicine is contraindicated. It will also look for contraindications between multiple drugs. This along with the fact that illegible handwriting is no longer an issue may decrease the potential for prescribing errors. An example of a prescription is shown in Figure 7.



UAB Health Center Huntsville - Family Medicine Center
301 Governors Drive, Huntsville, AL 35801
256-551-4500

Name _____ MRN 50001544

Address *(HP), 301 GOVERNORS DR, HUNTSVILLE, AL 35801* DOB 01/01/2005

Aspirin Childrens 81 MG Tablet Chewable #30

Quantity: (thirty tablet chewable)

This is only a test. Thanks!

dispense as written

product selection permitted

Written: 04/10/2008 ***Refills Authorized 0 Times*** *Rx:* 7822294

Figure 7. Prescription for Aspirin printed automatically by the EMR

Placing orders for testing is done in the order entry workspace in the order module as shown in Figure 8. The order module offers a list of all available labs and requires them to be linked to a diagnosis before being ordered. The module checks to make sure that the orders are needed based on the diagnosis provided. The module also prints lab requisitions with clear orders on them in order to prevent confusion when the patient arrives at testing facilities. The orders module is also used to have referrals scheduled.

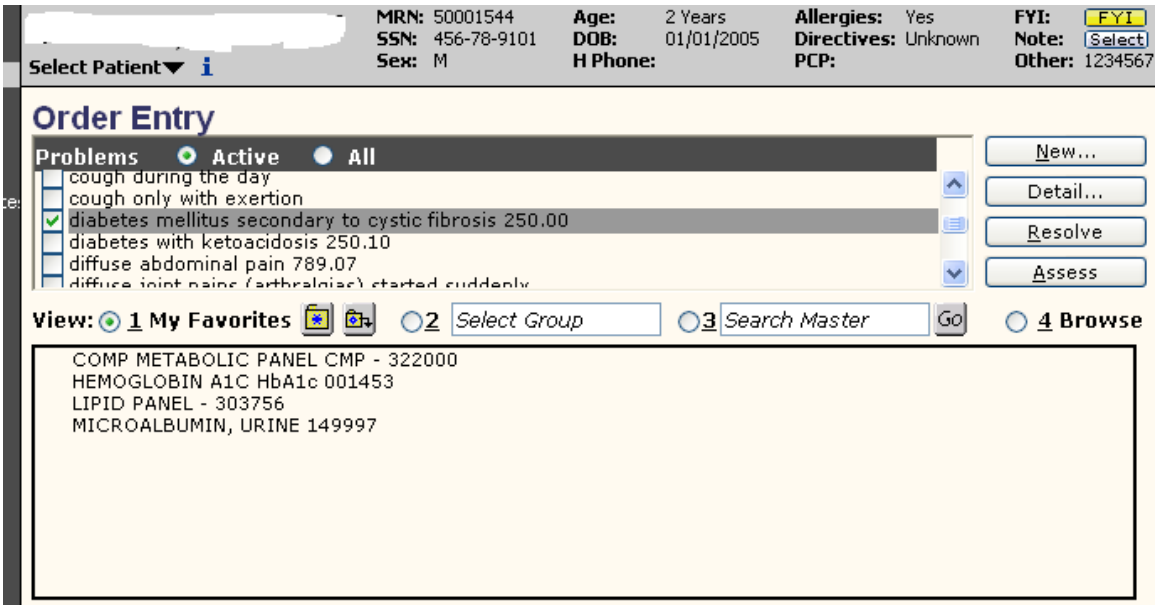


Figure 8. The Order Entry system being used to place orders for a diabetic

One major benefit of the order entry screen is that each physician can create a default view that lists only the items ordered most often. For example, if physicians see a lot of diabetic patients they would have the recommended labs for a diabetic in their favorites list. This is a dynamic list that can be changed by the end user at any time. The system routes all referral requests to the proper clinic staff for completion via the workflow module. The system is also used to order in house tests that will be performed by the staff. The in house tests can be documented by the staff in the system.. All medications and orders made will be documented in the note automatically.

The physician will now document the plan and will conduct any counseling or patient education that is needed. The remainder of the visit documentation includes an

attending statement verifying the work of the residents and the creation of the encounter form for billing purposes.

The workflow module allows all tasks that are generated into the clinic to be entered in to the system and tracked. The system is used to relay information from patient, pharmacy, and outside physicians to the clinical entities in the clinic within an efficient manner. The primary benefit is that tasks can no longer be lost as they could when they were simply written on paper slips. This system is also used to notify physicians of completed labs, imaging reports, completed notes, and when they need to submit charges. The system also allows the physician to create orders that are sent to the staff for completion. Figure 9 shows a screenshot of a task being sent.

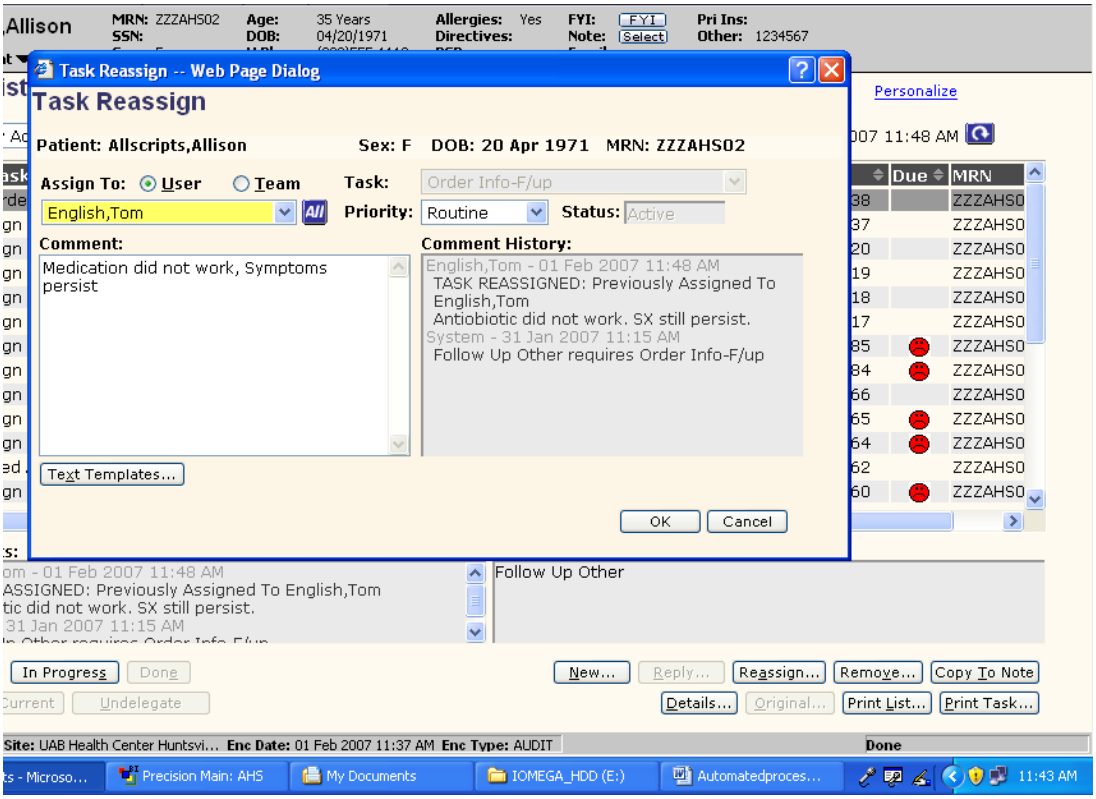


Figure 9. The workflow module is being used to follow up on a patient's medications.

The Charge module builds the charge slip based on the information that is provided in the note. It also recommends a charge based on the components that were used in the note.

The Result module, shown in Figure 10, allows physicians and staff to view the results of tests on the system. UASoMH has an electronic interface with two facilities in order to have results come over instantly. New results automatically create a task for the physician to review them. The system also has the capability of creating a graph of historical labs to easily see the trends in a patients lab results. Labs that are not sent into the system electronically are scanned in and a task is then sent to the physician to review.

Scanned results do not interact with other parts of the system. The vast majority of the results come over on one of the electronic interfaces. The scan module will be discussed later.

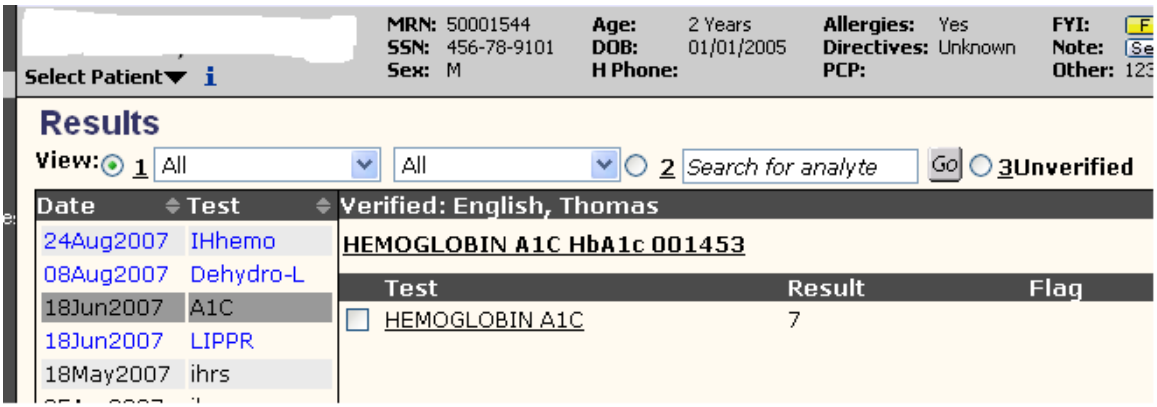


Figure 10. Result Module

The scan module allows the medical records staff to quickly get into the system all information that comes in only paper format. The scan module has been created to have several folders and document types so that the scanned documents are easily identifiable.

The system also has a feature named Quicksets. If a physician uses Quicksets, all the orders they have ever associated with a specific problem will be automatically generated in a pick list of orderable items. For example, if a doctor ordered a HbA1c and a Lipid Panel on a patient with diabetes; the next time they viewed Quicksets on any patient with diabetes, the HbA1c and Lipid Panel would automatically appear and could be ordered if needed. The Quicksets module is shown in Figure 11

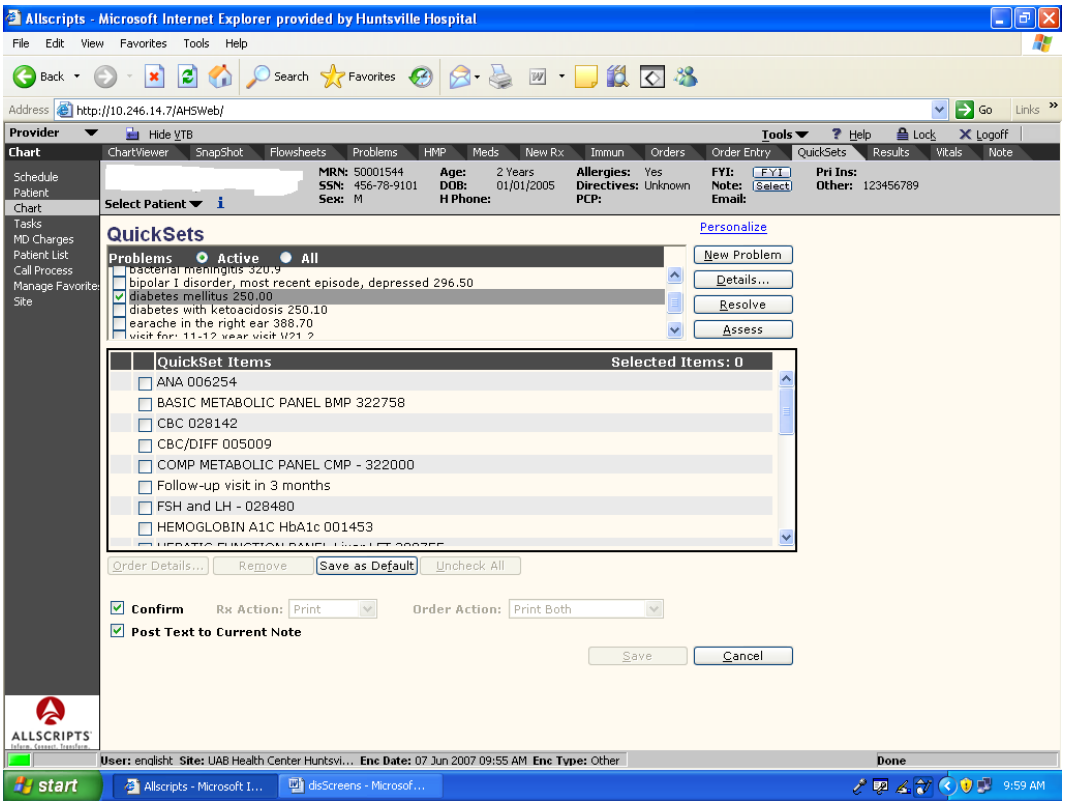


Figure 11. Quicksets

The system also has a Health Maintenance Plan (HMP) section. This allows a provider to create reminders on specific patients about when particular test and other orderables need to be completed for a patient. For example, a doctor may create an HMP saying that a diabetic patient needs an HbA1c every 3 months. When a patient comes in and is past due for the HbA1c a warning icon will appear on the patients chart in order to inform the physician that the HbA1c needs to be done. An example HMP is shown inFigure 12.

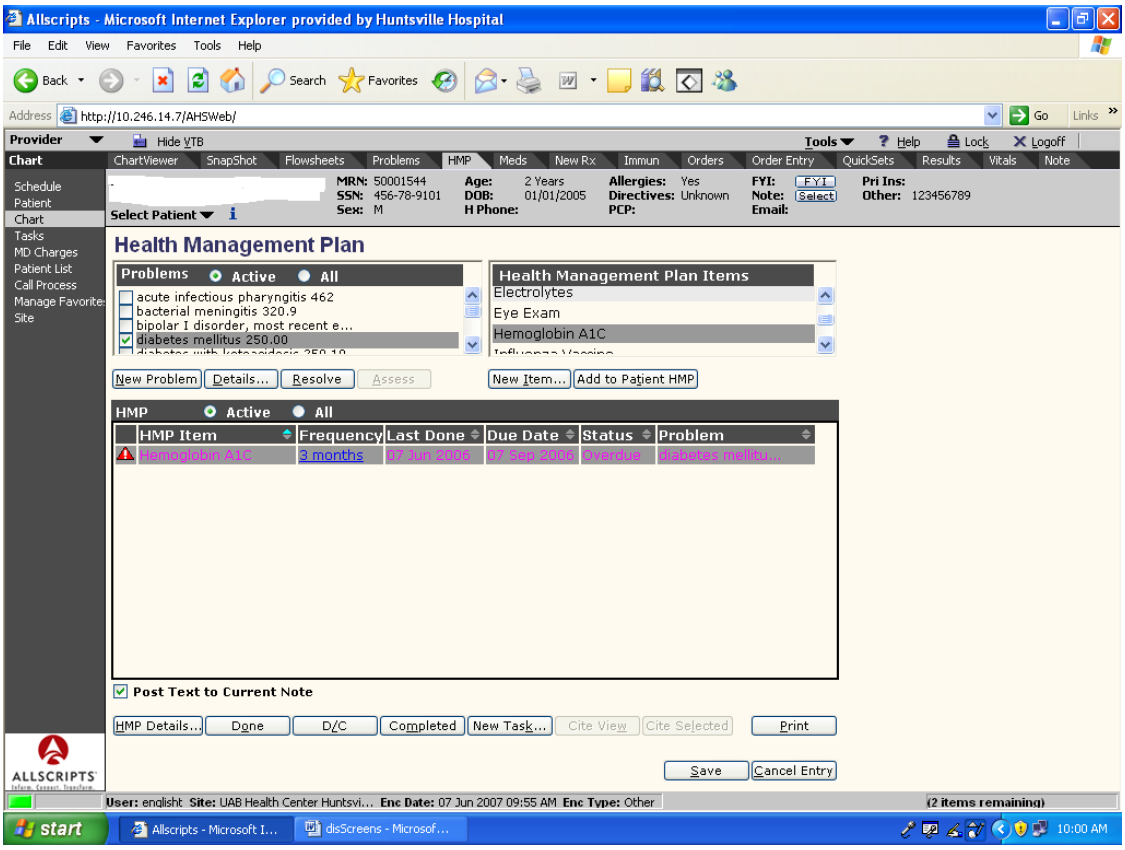


Figure 12. Health Maintenance Plans

The workflow described is what users were trained to do and what is used most often. Users do have options to use the system in different manners but all the information presented is available to all users.

Sample

The present study was designed as a retrospective chart review of diabetic patients from the UASoMH Family Medicine Clinic. All data was generated from chart audits. The pre-EMR data was manually audited and the post-EMR data was audited using a query tool linked to the EMR. All adult patients diagnosed with diabetes in a defined time period were included in the study. In the pre period patients identified as diabetics with an office visit between 8/15/05 to 8/15/06 were included. For the post period the sample included all diabetic patients with office visits between 8/16/07 and 6/19/08. Once the final visit date for each patient in a time period was indexed chart audits were done. A one year patient history was audited working from the index point into the past. The year ended with the date identified as the last visit in the time period and went back one year. This was done so that patients in the pre group had a full year of care without the EMR and post patients would have a full year of care with the EMR.

Measures

The study is designed to evaluate the changes in diabetic care and diabetic outcomes pre and post EMR implementation. This research focuses specifically on the orders and guidance offered by the physician and not necessarily the actions taken by the patient. Patterns of care will be assessed based on adherence to treatment guidelines. Treatment guidelines are included in this study if the action item is in the physician's control, the action is required at least once per year, and the action is valid for the vast

majority of diabetics. The primary focus of the study is to understand if the physicians ordered the tests or not. Next the study examines the number of patients that actually had a test performed. This second portion will provide insight into patient compliance. The tertiary goals of the study are to examine if the EMR actually had impact on intermediate diabetic outcomes.

Null Hypotheses:

1) The odds of a patient having diabetic testing ordered is the same both pre and post EMR implementation.
2) The odds of a patient having diabetic testing completed is the same both pre and post EMR implementation.
3) The odds of a patient having control over their intermediate diabetic markers is the same both pre and post EMR implementation.

To reject the null hypothesis the EMR has to be found to be associated with a change in the probability of labs being ordered, being performed, and lab results being controlled.

Dependent Variable

Patterns of care will be measured by looking at the changes of order rates of labs recommended for all diabetics.

Primary: Dichotomous variable: Did the patient have an HbA1c order in the last 6 months?

Secondary: Dichotomous variable: Did the patient have an HbA1c test performed in the last 6 months?

Tertiary: Dichotomous variable: Was the HbA1c result greater than or equal to 7%?

Primary: Dichotomous variable: Did the patient have an LDL cholesterol screening test ordered in the last year?

Secondary: Dichotomous variable: Did the patient have an LDL cholesterol screening test performed in the last year?

Tertiary: Dichotomous variable: Was the LDL cholesterol result greater than or equal to 100 mg/dL?

Primary: Dichotomous variable: Did the patient have a microalbuminuria test ordered in the last year?

Secondary: Dichotomous variable: Did the patient have a microalbuminuria test performed in the last year?

Tertiary: Dichotomous variable: Was the microalbuminuria result greater than or equal to 20 µg/mg?

The primary variables will all be based on what orders were made by the physicians. This differs from previous studies because it eliminates the issue of patient compliance and looks specifically at whether or not the physicians are following guidelines.

Independent Variable

The EMR Intervention will be the independent variable of interest. All cases prior to the EMR installation are coded with a zero and all cases that occurred post EMR installation are coded with a one.

Covariates

Patient age, gender, insurance, number of appointments, and co morbidities will be controlled for. Operationalization of the variables is discussed below.

Design

The study is designed to evaluate the changes in diabetic care and outcomes pre and post EMR implementation. The study will test the hypothesis that the EMR is associated with patterns of diabetic care using a Pre-Test/Post-Test Design.

Estimation Technique

Generalized Estimating Equations (GEE) were used to determine the relationship of the EMR with diabetes care and intermediate diabetes outcomes. This method was

chosen because it can account for the multiple measures for many of the patients. It was developed by Zeger and Liang in order to handle correlated data (115). The dependent variables will be lab orders. The independent variable will be whether the EMR was in place. Covariates will be controlled for. All dependent variables will be considered individually.

GEE models were used to identify statistically significant independent predictors of adherence to diabetes care guidelines. These guidelines include ordering HbA1c, Lipid, and Microalbumin tests

Covariates included in the GEE models are measured in the following ways.

Patient age (Measured continuously)

Gender (Male=1 vs. Female=0)

Insurance (Private vs. Medicare vs. Medicaid vs. Uninsured) 3 Dummy variable will be used with Medicare being the state the other three are measured against.

1) Medicaid: Patient with Medicaid=1 vs. all others= 0
2) Private: Patient with private insurance=1 vs. all others= 0
3) Uninsured: Patients without insurance=1 vs. all others= 0

Numbers of appointments in a given time frame will be measured continuously. The HbA1c models will consider appointments in the last six months and the other models will consider visits in the last year.

Many common co morbidities will be included in the model. Every co morbidity will be operationalized in the model with a dummy variable.

1) Hypertension=1 vs. No Hypertension =0
2) Hyperlipidemia=1 vs. No Hyperlipidemia =0
3) Nephropathy=1 vs. No Nephropathy =0
4) Neuropathy=1 vs. No Neuropathy =0
5) Retinopathy=1 vs. No Retinopathy =0
6) CAD=1 vs. No CAD =0
7) COPD=1 vs. No COPD =0
8) Depression=1 vs. No Depression =0

All GEE models include the same set of predictor variables with one exception. The HbA1c models will use a variable for appointments in the last six months and the other models will use a variable that accounts for all visits in a year. The GEE models will all be set up using the same criteria. The models will be set up similar to logistic regression by using a binomial distribution and a logit link.

The working correlation matrix will be use the AR(1) criteria which assumes that repeated measures have an autoregressive relationship. This matrix was needed because

some patients have cases included in the sample in both the pre and post time periods. Differences are considered statistically significant at the $p < .05$ level. All statistical analysis was done is SPSS version 15 (116).

CHAPTER 4—RESULTS

Data was collected on 1259 diabetic patients covering 1760 cases. The pre group totaled 838 cases and the post group included 922 cases. A group of 501 patients had cases in both the pre and post periods. Additionally, 337 patients were only in the pre group and 421 patients were only in the post group. Subset analysis of just the patients with multiple cases and just those with one case were conducted and both sets of results were comparable to the findings for the entire study population. Only the results from the entire population are reported.

Demographic Comparison

Demographics are reported in Table 1 below for pre and post group patients. The only significant difference between the pre and post groups was in the percentage of uninsured patients. Before the EMR 6% of the patients were uninsured and post EMR implementation 4% were uninsured. No differences were found in the other insurance categories, gender, number of visits, or in the rates of co morbidities.

Table 1. Demographic Comparison Pre and Post EMR

	Pre EMR n=838	Post EMR n=922	P-Value
AGE	59.73	58.76	0.120
Appt. in 6 months	3.33	3.40	0.457
Appt. in 1 year	5.47	5.61	0.404
Male	40%	39%	0.916
INSURANCE			
Uninsured	6%	4%	0.029
Medicare	42%	45%	0.201
Medicaid	21%	18%	0.100
Private Insurance	31%	33%	0.283
COMORBIDITIES			
Hypertension	80%	80%	0.731
Hyperlipidemia	54%	52%	0.464
Nephropathy	5%	4%	0.312
Neuropathy	14%	15%	0.655
Retinopathy	4%	3%	0.707
CAD	13%	12%	0.544
COPD	9%	9%	0.658
Depression	16%	19%	0.165

HbA1c ordering, testing, and control rates for the pre and post periods are displayed in Figure 13 below. In the pre and post period ordering and performing rates were approximately the same for all 1760 patients. The 1177 with HbA1c results were more likely in the post period to have control of their HbA1c (p=0.033).

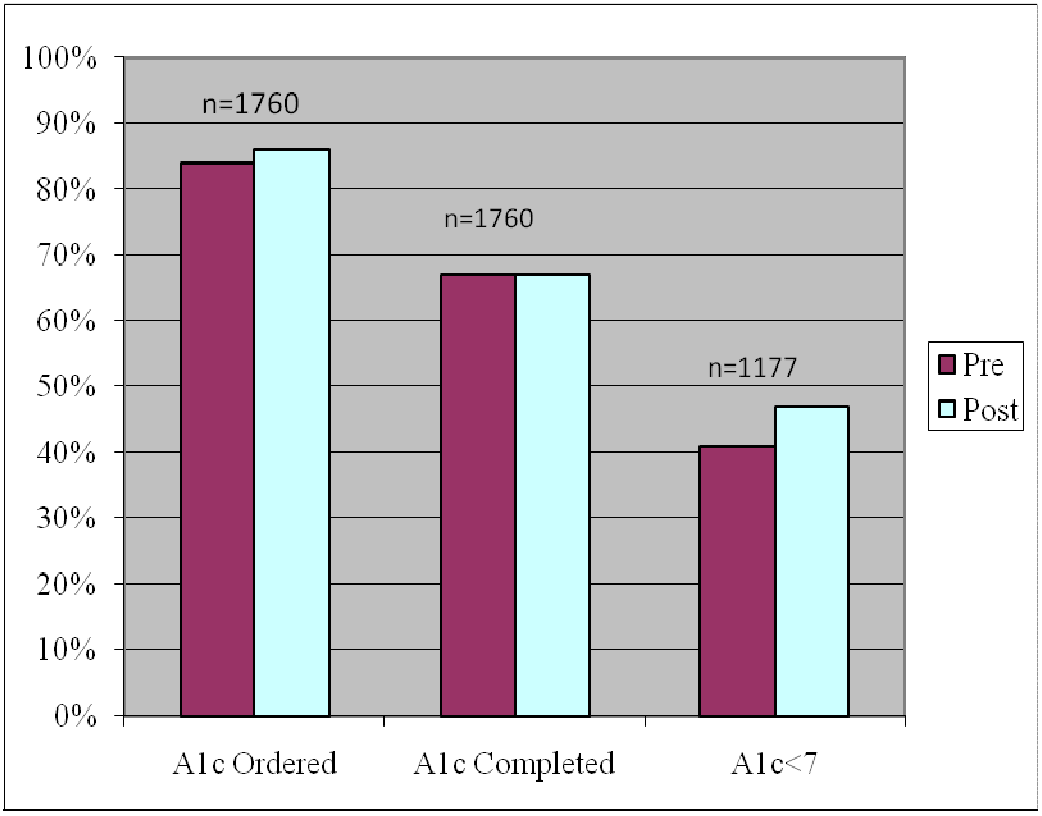


Figure 13. HbA1c Rates Pre and Post EMR

The rates of LDL ordering, testing, and control for the pre and post periods is shown in Figure 14. In the pre and post period ordering and performing rates were approximately the same for all 1760 cases. The 1299 cases with LDL results were more likely in the post period to have control of their LDL ($p<0.001$).

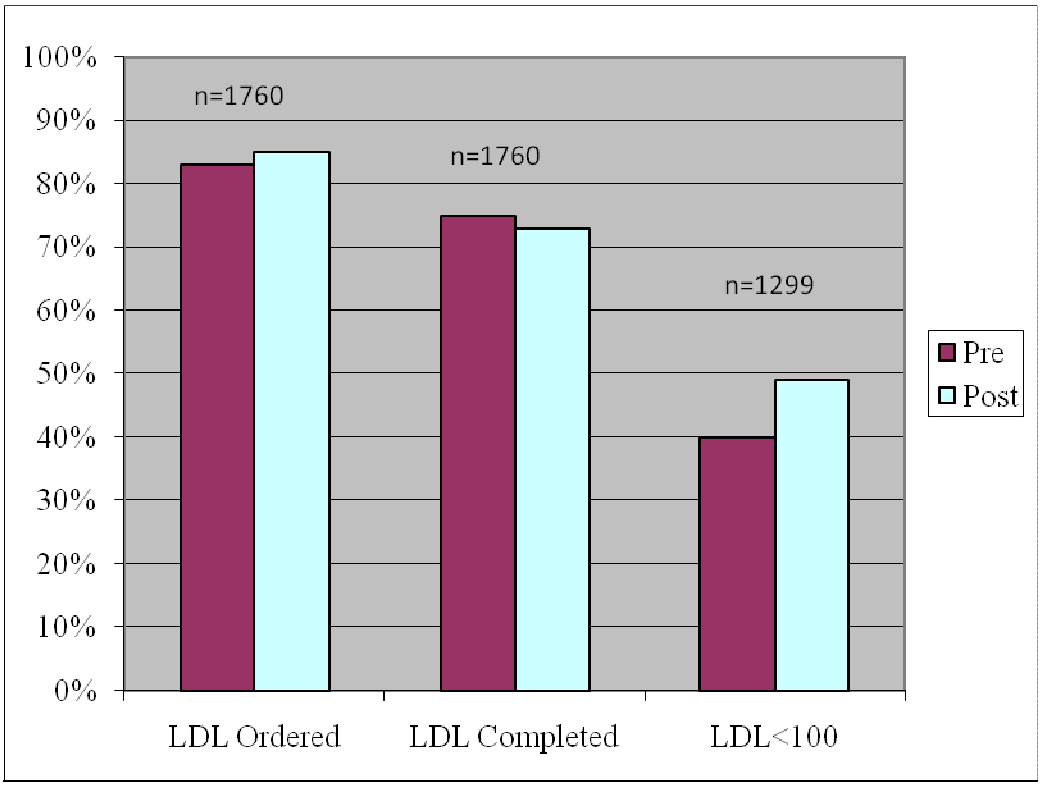


Figure 14. LDL Rates Pre and Post EMR

Microalbumin ordering, testing, and control for the pre and post periods is shown in Figure 15. In the post period patients were more likely to have a test ordered ($p<0.001$) and patients were more likely to have the tests completed ($p<0.001$) for the entire sample of 1760 cases. Patients that had a microalbumin result were more likely to have control of their microalbumin in the post period ($p<0.001$).

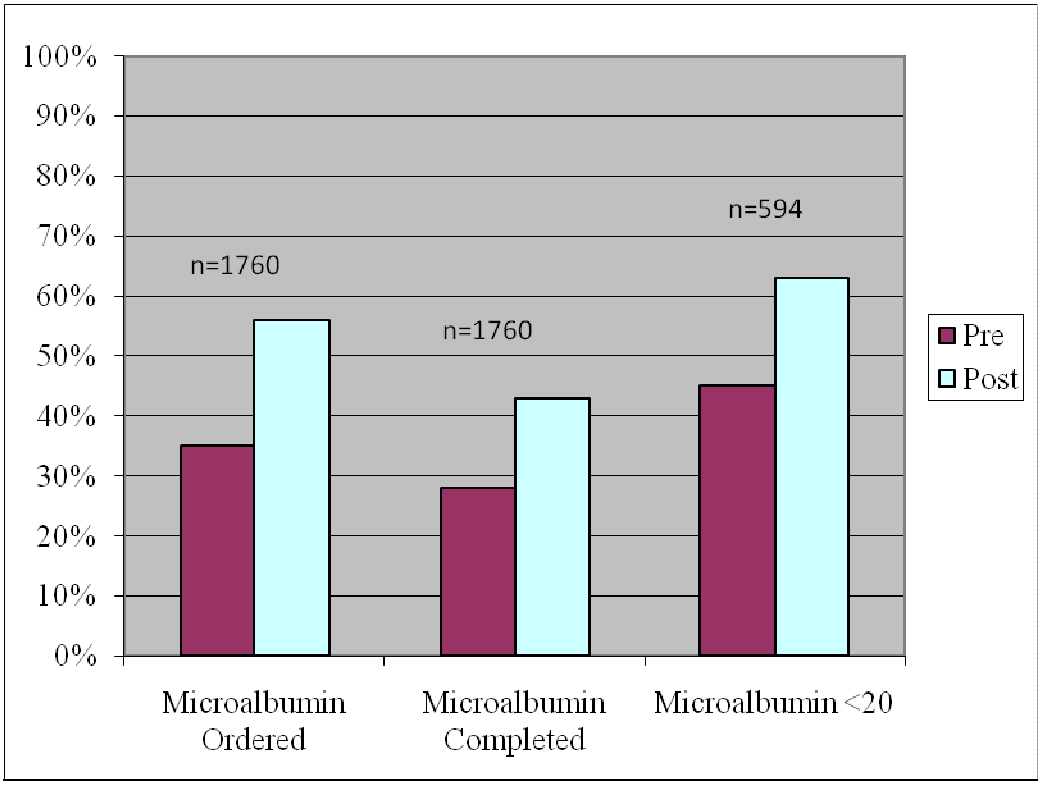


Figure 15. Microalbumin Rates Pre and Post EMR

Measures

The primary measures of the study were to determine if implementation of the EMR was associated with changes in the frequency with which providers ordered three lab tests recommended for all diabetics. Separate analysis was done for HbA1c, LDL cholesterol, and microalbumin orders. The secondary models were used to determine if patients were more likely to have tests performed and the tertiary models were used to determine if patients were more likely to control the intermediate outcomes. This section walks through the results of the 9 GEE models that were run. The HbA1c, LDL, and microalbumin models will be shown in that order. For each lab test models are shown relating to order rates, performance rates, and control in that order.

HbA1c

The GEE model exploring the relationship of the EMR with HbA1c orders is summarized in Table 2. HbA1c tests were 26% more likely to be ordered post EMR implementation but the difference was not significant ($p=0.079$). Several covariates were significant in the model. Patients on Medicaid were twice as likely to have an HbA1c ordered than those on Medicare. Patients on private insurance were 70% percent more likely to have an HbA1c ordered than those on Medicare ($p=0.004$). Hypertensive patients were 93% more likely to have a HbA1c ordered than non hypertensives ($p<0.001$). Hyperlipidemic patients were 61% more likely to have an HbA1c ordered than

non hyperlipidemics ($p=0.002$). For each additional appointment a patient has they are 22% more likely to have an HbA1c ordered ($p<0.001$).

Table 2. GEE Model Considering HgbA1c Orders as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	0.235	1.265	0.079
Male	0.000	1.000	0.998
AGE	0.003	1.003	0.561
Uninsured	-0.515	0.598	0.064
Medicaid	0.694	2.002	0.004
Private	0.528	1.696	0.004
Appt_6_months	0.201	1.223	<0.001
HTN	0.659	1.934	<0.001
HLIP	0.478	1.613	0.002
NEPH	0.722	2.058	0.091
NEURO	-0.148	0.862	0.481
RETIN	-0.243	0.784	0.507
CAD	-0.335	0.716	0.101
COPD	0.010	1.010	0.968
Depression	0.037	1.037	0.858
(Intercept)	-0.118	0.889	0.777
Variable: A1c order (yes=1)		n=1760	

A summary of the GEE used to explore the relationship between the EMR and HbA1c performance rates is shown in Table 3 HbA1c tests were 1% less likely to be

performed post EMR implementation but the difference was not significant (p=0.950). Several covariates were significant in the model. Uninsured patients were 62% less likely to have an HbA1c performed than those on Medicare (p<0.001). Patients on private insurance were 35% percent more likely to have an HbA1c performed than those on Medicare (p=0.030). Hypertensive patients were 64% more likely to have an HbA1c performed than non hypertensives (p<0.001). Hyperlipidemic patients were 47% more likely to have an HbA1c performed than non hyperlipidemics (p<0.001). For each additional appointment, a patient has they are 37% more likely to have an HbA1c performed (p<0.001).

The GEE model used to assess the relationship of the EMR and HbA1c control is displayed in Table 4. Patients in the post EMR group were 20% more likely to have an HbA1c<7% than those seen pre EMR (p=0.033). Older patients were more likely to have their HbA1c<7%. For each year of age the likelihood of being controlled increased by 1% (p=0.022).

Table 3. GEE Model Considering HgbA1c Performed as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	-0.006	0.994	0.950
Male	0.107	1.113	0.357
AGE	0.008	1.008	0.087
Uninsured	-0.967	0.380	0.000
Medicaid	0.250	1.284	0.150
Private	0.299	1.348	0.030
Appt_6_months	0.312	1.367	<0.001
HTN	0.497	1.644	<0.001
HLIP	0.384	1.468	0.001
NEPH	0.250	1.284	0.483
NEURO	-0.035	0.965	0.834
RETIN	0.332	1.394	0.340
CAD	-0.048	0.953	0.788
COPD	-0.054	0.947	0.794
Depression	-0.082	0.922	0.596
(Intercept)	-1.434	0.238	<0.001
Variable: A1c performed (yes=1)		n=1760	

Table 4. GEE Model Considering HgbA1c>=7 as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	-0.229	0.795	0.033
Male	0.149	1.161	0.272
AGE	-0.013	0.988	0.022
Uninsured	0.795	2.215	0.064
Medicaid	0.211	1.235	0.264
Private	0.181	1.198	0.244
Appt_6_months	-0.022	0.978	0.485
HTN	0.221	1.247	0.208
HLIP	-0.077	0.925	0.554
NEPH	0.001	1.001	0.999
NEURO	0.269	1.308	0.148
RETIN	0.367	1.444	0.319
CAD	0.310	1.363	0.108
COPD	-0.160	0.852	0.479
Depression	0.159	1.172	0.353
(Intercept)	0.753	2.124	0.067
Variable: A1c>=7 (yes=1)		n=1177	

LDL

The changes in the patterns care and outcome concerning the HbA1c is mixed. Patients were more likely to have orders done but this increase did not translate into an increase in the amount of tests performed. Patients in the post EMR group were more likely to have their HbA1c controlled than those in the pre EMR group. This suggests that the EMR may have impacted HbA1c levels but it was not due to changes in testing rates.

LDL tests were 18% more likely to be ordered post EMR implementation but the difference was not significant ($p=0.213$) as shown in the summary of the GEE model that looked at the relationship of the EMR to LDL orders in Table 5. Several covariates were significant in the model. Uninsured patients were 50% less likely to have an LDL ordered than Medicare patients ($p=0.016$). Hypertensive patients were 67% more likely to have a LDL ordered than non-hypertensives ($p=0.001$). Hyperlipidemic patients were 150% more likely to have a LDL ordered than non hyperlipidemics. For each additional appointment a patient has they are 16% more likely to have a LDL ordered ($p<0.001$).

Table 5. GEE Model Considering LDL Orders as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	0.166	1.180	0.213
Male	-0.042	0.958	0.778
AGE	-0.007	0.993	0.250
Uninsured	-0.708	0.492	0.016
Medicaid	0.395	1.485	0.083
Private	0.319	1.375	0.076
HTN	0.514	1.672	0.001
HLIP	0.939	2.556	<0.001
NEPH	-0.071	0.932	0.868
NEURO	0.138	1.148	0.565
RETIN	0.020	1.020	0.960
CAD	0.047	1.048	0.830
COPD	-0.222	0.801	0.363
Depression	-0.084	0.919	0.684
Appt_year	0.146	1.157	<0.001
(Intercept)	0.406	1.501	0.369
Variable: LDL ordered (yes=1)		n=1760	

LDL tests were 11% less likely to be performed post EMR implementation but the difference was not significant (p=0.327) as shown in Table 6.Several covariates were significant in the model. Uninsured patients were 52% less likely to have an LDL performed than Medicare patients (p=0.004). Hypertensive patients were 74% more likely to have a LDL performed than non hypertensives (p<0.001). Hyperlipidemic patients were 125% more likely to have a LDL performed than non hyperlipidemics (p<0.001). For each additional appointment, a patient has they are 21% more likely to have a LDL performed (p<0.001).

The GEE model looking at the relationship of the EMR to LDL control shown in Table 7 found that patients in the post EMR group were 34% more likely to have a LDL<100 than those in the pre group with a significant (p<0.001). Older patients were more likely to have their LDL<100. For each year of age the likelihood of being controlled increased by 3% (p<0.001). Several covariates were significant in the model. Hyperlipidemic patients were 36% more likely to have a LDL <100 (p=0.015). For each additional appointment a patient has they are 3% more likely to have a LDL<100 (p=0.048).

Table 6. GEE Model Considering LDL Performed as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	-0.114	0.892	0.327
Male	-0.109	0.897	0.375
AGE	-0.001	0.999	0.792
Uninsured	-0.783	0.457	0.004
Medicaid	0.146	1.158	0.420
Private	0.184	1.202	0.213
HTN	0.554	1.740	<0.001
HLIP	0.811	2.250	<0.001
NEPH	-0.165	0.848	0.648
NEURO	-0.158	0.854	0.374
RETIN	0.520	1.682	0.160
CAD	0.135	1.144	0.458
COPD	-0.176	0.839	0.383
Depression	0.041	1.042	0.802
Appt_year	0.189	1.209	<0.001
(Intercept)	-0.569	0.566	0.130
Variable: LDL performed (yes=1)		n=1760	

Table 7. GEE Model Considering LDL>=100 as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	-0.413	0.662	<0.001
Male	-0.354	0.702	0.008
AGE	-0.026	0.974	0.000
Uninsured	-0.063	0.939	0.858
Medicaid	-0.176	0.839	0.346
Private	-0.173	0.841	0.264
HTN	0.197	1.217	0.245
HLIP	0.310	1.364	0.015
NEPH	-0.164	0.849	0.586
NEURO	-0.020	0.980	0.912
RETIN	0.309	1.363	0.406
CAD	-0.160	0.852	0.394
COPD	0.205	1.228	0.351
Depression	-0.112	0.894	0.505
Appt_year	-0.035	0.965	0.048
(Intercept)	2.125	8.377	<0.001
Variable: LDL>=100 (yes=1)		n=1299	

The results for the LDL test are somewhat similar to what is seen with the HbA1c. Order rates went up slightly but the change was not significant. Once again the changes in order rates did not translate into increase numbers of patients performing the tests. It was found that patients in the post period were more likely to control their LDL levels.

Microalbumin

Microalbumin order rates and their relationship with the EMR were analyzed in the GEE model summarized in Table 8. Microalbumin tests were 147% more likely to be ordered post EMR implementation and the difference was significant ($p<0.001$). Several covariates were significant in the model. Older patients were less likely to have a microalbumin ordered. For each year of age they were 1% less likely to have an order ($p=0.006$). Patients with private insurance were 34% more likely to have a microalbumin ordered than Medicare patients ($p=0.025$). Hypertensive patients were 40% more likely to have a microalbumin ordered than non hypertensives ($p=0.016$). Hyperlipidemic patients were 44% more likely to have a microalbumin ordered than non hyperlipidemics ($p=0.001$).

Table 8. GEE Model Considering Microalbumin Orders as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	0.904	2.471	<0.001
Male	-0.084	0.920	0.461
AGE	-0.012	0.988	0.006
Uninsured	-0.063	0.939	0.813
Medicaid	0.236	1.266	0.139
Private	0.291	1.337	0.025
HTN	0.338	1.403	0.016
HLIP	0.365	1.441	0.001
NEPH	0.396	1.486	0.190
NEURO	0.181	1.198	0.236
RETIN	-0.085	0.918	0.810
CAD	0.068	1.071	0.683
COPD	-0.162	0.851	0.392
Depression	0.111	1.118	0.425
Appt_year	0.029	1.029	0.075
(Intercept)	-0.740	0.477	0.022
Variable: Microalbumin performed (yes=1)			n=1760

The GEE model assessing the relationship of microalbumin performance rates and the EMR is summarized in Table 9. Microalbumin tests were 98% more likely to be performed post EMR implementation and the difference was significant ($p<.001$). Several covariates were significant in the model. Older patients were less likely to have a microalbumin ordered. For each year of age they were 1% less likely to have a test performed ($p=0.011$). Patients with private insurance were 37% more likely to have a microalbumin performed than Medicare patients ($p=0.017$). Hypertensive patients were 51% more likely to have a microalbumin performed than non hypertensives ($p=0.005$). Hyperlipidemic patients were 53% more likely to have a microalbumin performed than non-hyperlipidemics ($p<0.001$).

Microalbumin control was improved after EMR implementation based on results of the GEE model shown in Table 10. Patients in the post period were 55% more likely to have a microalbumin<20 than those in the pre period ($p<0.001$). Patients with CAD were 129% more likely to have a poorly controlled microalbumin over 20 ($p=0.005$).

Table 9. GEE Model Considering Microalbumin Performed as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	0.683	1.981	<0.001
Male	-0.161	0.851	0.165
AGE	-0.011	0.989	0.011
Uninsured	-0.375	0.687	0.214
Medicaid	0.187	1.206	0.251
Private	0.315	1.370	0.017
HTN	0.417	1.517	0.005
HLIP	0.426	1.531	<0.001
NEPH	0.434	1.544	0.127
NEURO	0.154	1.167	0.324
RETIN	0.000	1.000	0.999
CAD	0.173	1.189	0.292
COPD	-0.192	0.825	0.341
Depression	-0.079	0.924	0.580
Appt_year	0.049	1.050	0.003
(Intercept)	-1.226	0.294	<0.001
Variable: Microalbumin performed (yes=1)			n=1760

Table 10. GEE Model Considering Microalbumin>=20 as the Dependent Variable.

	Beta	Odds Ratio	Sig.
EMR	-0.808	0.446	<0.001
Male	-0.171	0.843	0.400
AGE	-0.009	0.991	0.245
Uninsured	0.176	1.193	0.734
Medicaid	0.268	1.307	0.315
Private	-0.255	0.775	0.253
HTN	0.022	1.022	0.936
HLIP	-0.020	0.981	0.918
NEPH	0.769	2.159	0.071
NEURO	0.392	1.480	0.102
RETIN	0.788	2.199	0.215
CAD	0.827	2.287	0.005
COPD	-0.488	0.614	0.187
Depression	-0.194	0.823	0.414
Appt_year	-0.008	0.992	0.797
(Intercept)	0.779	2.179	0.206
Variable: Microalbumin>=20(yes=1)			n=594

Microalbumin order and performing rates both increased significantly in the post period. The rates of control also improved significantly.

Table 11 gives a summary of the impact of the EMR on the dependent variables as found in the different GEE models.

Table 11. Summary of the EMR Impact from the GEE Models

	Beta	Odds Ratio	Sig.
Control			
A1c>=7	-0.229	0.795	0.033
LDL>=100	-0.413	0.662	<0.001
Microalbumin >=20	-0.808	0.446	<0.001
Tests Ordered			
HbA1c Order	0.235	1.265	0.079
LDL Ordered	0.166	1.180	0.213
Microalbumin Ordered	0.904	2.471	<0.001
Tests Completed			
A1c Completed	-0.006	0.994	0.950
LDL Completed	-0.114	0.892	0.327
Microalbumin Completed	0.683	1.981	<0.001

The order rates for all 3 tests increased post EMR but the change was statistically insignificant for the HbA1c and LDL orders. The performance rates for the microalbumin increased but the rates for the other tests did not. Interestingly, all 3 intermediate outcomes were more likely to be controlled post EMR.

CHAPTER 5—DISCUSSION

All of the null hypotheses are rejected. The odds of a patient having diabetic testing ordered increased for at least one measure after EMR implementation. The odds of a patient having diabetic testing performed increased for at least one measure after EMR implementation. The odds of a patient having control over their intermediate diabetic markers increased for all three measures after EMR implementation. The study found that the implementation of the EMR coincided with an increase in the order rates of microalbumin tests and with an improved control of HbA1c, LDL, and microalbumin.

The HbA1c and the LDL measures followed similar patterns. The order and performance rates were approximately the same in both the pre and post time periods. However the ordering and performance patterns of microalbumin testing did improve.

The microalbumin order rates were the most likely to increase significantly because the order rates pre EMR were very low. The order rates of the HbA1c and LDL were high in the pre period which left little room for improvement. Despite the improvement seen in the microalbumin order rates, substantial room for improvement exists. It is, however, unclear if changing ordering rates is needed as a disassociation of order rates and intermediate outcomes was observed.

This disassociation between guidelines and outcomes is a known phenomenon and has been observed during diabetes quality improvement studies (105, 106, 114). This is reflected in the guidelines as the level of evidence for the orders that were used as dependent variables is all based on expert opinion and not on scientific studies (15).

The results of this study and prior studies agree that a disassociation occurs. Prior studies saw changes in testing rates while this study is seeing changes in intermediate outcomes. The reason for the discrepancy is unknown and could very well be due to differences in the characteristics of the EMRs used.

The differences in our findings from prior research could have occurred for a variety of reasons. The baseline order and testing rates were much higher in this sample than the sample used in prior studies. This fact limits the opportunity to have a positive impact on order rates. Similar results have been seen when research was done on reminder systems (117).

Although the EMR implementation was associated with improved intermediate outcomes, the changes in HbA1c and LDL control rates were not achieved by changing the order rates of lab tests. That leaves the question of what aspect of the EMR may have influenced the control rates. Based on the Donabedian model one would expect changes in outcomes to be related to changes in order and testing rates which was not always the case.

This may also be associated with the fact that the process for getting results reviewed by physicians has been changed. Results come in electronically and physicians are electronically tasked to verify the results in a timely manner. Prior research has suggested that providers could offer better care if systems were in place to get results to them in efficient manners (118). It has also shown that these efficiencies may lead to quicker treatment of problems (119). Regardless of the relationship between results and medication management it is necessary to also consider that the system may have impacted prescribing which led to changes in intermediate outcomes.

Limitations

It was not possible to conclusively show cause and effect due to the nature of the research design. A control group was not available to determine if the effects observed were particular to our research group or if they were part of unmeasured factors causing the observed changes. The differences could have occurred due to outside factors. One potential factor is the clinic participated in a diabetes quality reporting project during this time period. However, that project worked with claims data only thus it is doubtful that it had much effect. It is doubtful a physician would look at the tools for the project during a visit. Further, the project did not cover microalbumin so it would not be associated with changes with that test. The residents go through a three year program so the physician group changes every year. This may play a role because individual physicians do vary but

the faculty staff is fairly consistent which likely tempers any impact that physicians changing could have.

Only one EMR was considered in this study, however, it was certified by The Certification Commission for Healthcare Information Technology (CCHIT) which means it has met certain standardized recommendations for EMRs. The CCHIT is pushing to increase adoption of EMRs by developing a credible credentialing system. The CCHIT is pushing for EMRs to interoperable, secure, and to offer useful clinical information (120).

The time frame of the study was brief only looking at one year for each time period. The EMR may not have its full effect for several years or it is possible that the changes that were seen could degrade in the future once a certain comfort level with the EMR is realized.

The study was done in a residency program so the changing of physicians may have contributed to the differences. Unfortunately, due to the nature of the clinic, continuity of care is poor so accounting for the physician was not possible. However, prior studies have shown that in most cases the physicians themselves have little impact on the variations in diabetes care (81, 85, 95, 97, 99, 102-104).

Strengths

This study does use a CCHIT certified EMR which partially resolves the problem of all EMRs being different. This study may not be generalizable to all EMRs but it may

be to other certified EMRs. Generalizability is still challenged because even if an EMR has functionality providers may not take advantage of it.

Microalbumin is typically not considered in projects similar to this. It is however an important test that is an excellent indicator of long term complications. While this study considered only a small set of the guidelines the addition of the microalbumin was valuable because it is an item that was often not ordered in the clinic in the study.

The study takes full advantage of the data in the EMR and therefore can look at the variables in multiple ways. This allowed for a more accurate view of how physician behavior changes, patient compliance, and outcomes. Without the EMR separating the physician changes and patient compliance would have been extremely difficult.

Conclusions

The EMR was associated with improvements across the board on intermediate outcomes but those changes cannot be attributed to physicians changing their ordering patterns as tested in this study. The EMR used in this study did have a system to remind physicians of routine orders however it was not integrated enough with the rest of the product for it to be useful. The reminders did not recognize when orders were placed and reset. Also the reminders had to be set up for each individual process. In the end the reminder system took far too much time for most of the providers to use.

The EMR offers the promise of better care delivered more efficiently. This will not occur until the practice of medicine is modified to take advantage of the tools the EMR has to offer. The EMR is a warehouse of data that in many situations can be easily queried. The system studied here had a backend tool that was used to extract data for this study. Those same extraction tools could be used to enhance healthcare. For instance, it is easy to identify all the diabetics that have not had an HbA1c done in the last 6 months. Providers could simply have a person generate this list and have them review notes to discover why tests have not been ordered. In this study, close to 20% of diabetics that came in did not have an order for an HbA1c. A member of the clinical staff could follow up on these patients to determine why the guidelines were not followed. In some instances, the diabetes may be followed and treated by another physician while, in other cases, the order may not have been placed because the patient has controlled their diabetes for a long time period and the test is not clinically necessary. In some cases the clinician may have forgotten to order the test.

Recommendations for Future Work

Further work on the impact of EMRs is needed. One problem with EMR research is that all EMRs are different. Working with programs that are CCHIT certified is highly recommended because it allows for the results to be generalized to other systems with the same certification. Work should also be done to look at how using the data in EMRs could be studied and implemented to change how healthcare is provided. Data mining is a simple task in many EMRs but few have used this feature as a tool to enhance care.

Work should also be done in pursuit of the exact mechanisms that caused the change seen in outcomes. One possible cause is the electronic prescribing. Assuming this link could be shown, it would add more evidence to the need for electronic prescribing.

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APPENDIX: INSTITUTIONAL REVIEW BOARD APPROVAL FORM

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines. The Assurance became effective on November 24, 2003 and expires on October 26, 2010. The Assurance number is FWA00005960.

Principal Investigator: ENGLISH, THOMAS M

Co-Investigator(s):

Protocol Number: **X080404002**

Protocol Title: *Impact of an Electronic Medical Record on Adherence to Current Diabetes Guidelines in a Family Medicine Center*

The IRB reviewed and approved the above named project on 4/15/08. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 4-15-08

Date IRB Approval Issued: 4/15/08

HIPAA Waiver Approved?: Yes
Partial HIPAA Waiver Approved?: No

Marilyn Doss

Marilyn Doss, M.A.
Vice Chair of the Institutional Review
Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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