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# **The Impact of EHR and Teamwork on Care Transitions and Patient Outcomes**

By

Ilana Paula Graetz

A dissertation submitted in partial satisfaction  
of the requirements for the degree of  
Doctor of Philosophy  
in  
Health Services and Policy Analysis  
in the Graduate Division  
of the  
University of California, Berkeley

Committee in charge:  
Professor Steve Shortell, Chair  
Professor Thomas Rundall  
Professor Steve Selvin  
Professor John Hsu

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## **ABSTRACT**

### **The Impact of EHR and Teamwork on Care Transitions and Patient Outcomes**

by: Ilana Paula Graetz

Doctor of Philosophy in Health Services and Policy Analysis

University of California, Berkeley

Professor Steve Shortell, Chair

While Electronic Health Records (EHR) systems have been consistently promoted as a policy priority for improving the quality and efficiency of the American healthcare system, there is limited research evidence to inform policy-makers on how the organizational context may impact any potential benefits from use of the EHR. For my dissertation, I leveraged the staggered nature of the EHR implementation at Kaiser Permanente Northern California (KPNC) to conduct a quasi-experimental study with concurrent controls evaluating the impact of a certified EHR and primary care team member's working relationships on measures of care coordination and quality for patients with diabetes.

I found that while the introduction of an outpatient EHR alone was associated with substantial improvements in care coordination across clinicians, it was not associated with improvements in coordination of care across delivery sites. Use of the integrated outpatient-inpatient EHR system was associated with significant improvements in coordination of care across delivery sites and across clinicians.

For both care coordination and physiologic disease control for patients with diabetes, I found a statistically significant interaction effect between primary care team cohesion and EHR use. While use of the integrated EHR was associated with significant improvements in care coordination across delivery sites for clinicians working in primary care teams with higher cohesion, there was no significant change in coordination from EHR use for clinicians working in teams with lower cohesion. For clinical outcomes, on average all patients benefited from the EHR, however, patients cared for by clinicians working in primary care teams with lower cohesion experienced significantly reduced improvements in their HbA1c and LDL-C levels as a result of the EHR compared with patients cared for by primary care teams with higher cohesion.

The organizational context, in particular primary care team members' working relationships, is critical to maximize any potential gains in care quality from EHR use. I found that clinicians work in teams with strong working relationships were able to leverage the tools available in the EHR to achieve significantly greater improvement in care. Health Information Technology, and specifically EHR, offer new opportunities for improving overall quality of care, preventing medical errors, and reducing health care costs. Still, EHR systems are not silver bullets and their impact on care quality and efficiency will be limited if any deficiencies of the work environment and team relationships are not mutually addressed.

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## CURRICULUM VITAE

**ILANA GRAETZ**

**NOVEMBER 2012**

3945 Altamont Ave  
Oakland CA, 94605  
[ilanag@gmail.com](mailto:ilanag@gmail.com)  
(925) 949-9755

### **Current Positions**

Doctoral Candidate, Health Services and Policy Analysis  
Designated emphasis in Organizations  
University of California, Berkeley

Data Analyst/Programmer  
Kaiser Permanente Division of Research, Oakland

### **Education**

Ph.D. 2007-2013 (expected)      University of California, Berkeley  
Dissertation Title:    *The Impact of EHR and Teamwork on  
Care Transitions and Patient Outcomes*  
Committee:             Steve Shortell (chair), Thomas Rundal,  
Steve Selvin, John Hsu

B.A. 1998-2002                    University of California, Berkeley  
Majors:                 Economics and Political Economies of Industrial  
Societies  
Minor:                    Demography

### **Awards and Fellowships**

2011-2012      AHRQ Dissertation Grant: "EHR and Care Coordination" (1R36HS021082-01)  
2011             Russell M. Grossman Endowment Award  
2010             Top Abstract for the conference, AcademyHealth Annual Research Meeting:  
"Preventive Care in Consumer Directed Health Plans: Do Consumers Avoid  
Deductible Exempt Care?"  
2009             University of Copenhagen Healthcare Services Research Fellowship  
2007-2008      Health Services and Policy Analysis Department Fellowship

### **Professional Experience**

2008-Present    Data Analyst/Programmer; Kaiser Permanente Division of Research, Oakland  
2004-2008      Research Associate; Kaiser Permanente Division of Research, Oakland

## Grants and Contracts

- 2011-2013      *EHR and Care Coordination*  
PI: Ilana Graetz, Agency for Healthcare Research and Quality (AHRQ)  
R36 Dissertation Grant (1R36HS021082-01)  
Role: Principal investigator
- 2012-2013      *Consumer-directed Health Plans and use of Online Tools*  
PI: Mary Reed, Kaiser Foundation Research Institute (KFRI) Community  
Benefit (CB) Grant  
Role: Contribute to study design, grant writing data collection, data  
analyses, and writing peer-reviewed manuscripts
- 2010-2014      *Impact of Integrated Health IT on Quality and Resource Use for Diabetic  
Patients*  
PI: Mary Reed, National Institute of Diabetes and Digestive and Kidney  
Diseases (NIDDK) R01  
Role: Contribute to the study design, grant writing, ongoing analysis,  
peer-reviewed manuscripts
- 2011-2012      *Implementation of the PECARN Traumatic Brain Injury Prediction Rules  
for Children Using Computerized Clinical Decision Support*  
PI: Dustin Ballard, Health Resources and Service Administration (HRSA)  
Role: Data analyst
- 2010-2013      *Population-Based Effectiveness in Asthma and Lung Diseases (PEAL)  
Network*  
PI: Stephen Soumerai, AHRQ R01  
Role: KPNC site project manager, data analyst
- 2010-2011      *Patient Use of Secure Electronic Messaging with Providers in KPNC*  
PI: Mary Reed, KFRI CB Grant  
Role: Contributed to study design, grant writing, data collection, data  
analyses, and writing peer-reviewed manuscripts
- 2009-2010      *Health insurance and access to care after discontinuation of KP  
employer-sponsored coverage*  
PI: Mary Reed, KFRI CB Grant  
Role: Contributed to study design, grant writing, data collection, data  
analyses, and writing peer-reviewed manuscripts
- 2004-2009      *Impact of Health Information Technology on Clinical Care*  
PI: John Hsu, AHRQ R01  
Role: Contributed to study design, data collection, and data analyses
- 2004-2006      *Methods for Developing Actionable Evidence for Consumers of Health  
Services Research (MATCH Study): Closing the Gap between  
Organizational Decision Makers and Researchers*  
PI: John Hsu, AHRQ  
Role: Project manager, contributed to writing peer-reviewed manuscripts



## **Publications**

Reed M, Graetz I, Fung V, Newhouse J, Hsu J. "In Consumer-Directed Health Plans, A Majority Of Patients Were Unaware Of Free Or Low-Cost Preventive Care." *Health Affairs*. December 2012; 31(12). In press.

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Rundall T, Martelli P, McCurdy R, Graetz I, Arroyo L, Neuwirth EB, Curtis P, Schmittdiel J, Gibson M, Hsu J. "Using Evidence When Making Decisions: Views of Health Services Managers and Policy Makers." In A. Kovner, R. D'Aquila and D. Fine (Eds.) *Evidence-Based Management in Healthcare*. Chicago: Health Administration Press. Pgs. 3-16.

## **Selected Presentations**

Graetz I, Reed M, Rundall T, Shortell S, and Hsu J. "EHR Use and Diabetes Care: Does Primary Care Team cohesion Moderate Improvements in Care Quality?" presented at AMIA Annual Symposium. Chicago, IL, November 2012.

Graetz I, Reed M, Huang J, Fung V, Veen A, Dow W, Bertko J, Newhouse J, and Hsu J. "COBRA ARRA Subsidies: Limits of a Carrot-Only Strategy?" presented at AcademyHealth 2011 Annual Research Meeting, Seattle, WA, June 2011.

Reed M, Fung V, Graetz I, Hsu J. "Preventive Care in Consumer Directed Health Plans: Do Consumers Avoid Deductible Exempt Care?" presented at AcademyHealth Annual Research Meeting June 2010, Boston MA. Awarded Top Abstract of the 2010 Annual Research Meeting.

Graetz I, Reed M, Rundall T, Bellows J, Brand R, and Hsu J. "Care Coordination and Electronic Health Records: Connecting Clinicians." presented at AMIA Annual Symposium. San Francisco, CA. November 2009.

Graetz I, Reed M, Huang J, Rundall T, Bellows J, and Hsu J. "Care Coordination and Electronic Health Records: Connecting the Medical Home with the Rest of the Village," presented at AcademyHealth 2008 Annual Research Meeting, Washington, DC, June 2008.

Graetz I, Reed M, Huang J, Rundall T, and Hsu J. "Care Coordination and Health Information Technology: Information Availability and Timeliness Across Care Transitions," presented at the 6th Annual HCQO Meeting, San Francisco, CA, May 2008.

Graetz I, Reed M, Fung V, Hsu J. "Systematic Use of Health Information Technology: Are We There Yet?" presented at AcademyHealth 2007 Annual Research Meeting, Orlando, FL, June 2007.

Graetz I, Fung V, Hsu J. "Electronic Communication with Patients: Who's Talking?" poster presented at Annual HMO Research Network Conference, Portland, OR, March 2007.

Graetz I, Reed M, Hsu J. "Cost-Sharing and Health Outcomes: A Systematic Review," poster presented at Annual HMO Research Network Conference, Santa Fe, NM April 2005.

## **Teaching Experience**

Spring 2008-2011      PH231A: Analytic Methods for Health Policy and Management; Teaching Assistant for Tim Brown

Fall 2010                PH150D: Introduction to Health Policy and Management; Teaching Assistant for Sandra Dratler

### **Professional Affiliations**

Member: Academy Health, American Medical Informatics Association (AMIA),  
American Public Health Association

Ad hoc reviewer: International Journal of Medical Informatics, Medicare & Medicaid  
Research Review

### **Software and Languages**

Software: STATA, R, and SAS

Languages: Fluent in Portuguese and English, and basic proficiency in Spanish and  
French

## CHAPTER 1: INTRODUCTION

The number of Americans living with chronic conditions is large and growing [1, 2]. These patients typically see multiple providers per year and take numerous prescription drugs [1-4]. Care for these patients is becoming increasingly complex and requires a high level of coordination to ensure quality care [2, 5]. Many institutions are promoting care coordination as a means for improving care quality and reducing inefficiencies of the US health care system, yet few validated instruments exist to measure levels of care coordination [1, 2, 6-10]. Lack of timely information and communication across clinicians often results in inadequate patient monitoring, redundant care, medical errors [10, 11], or greater use of hospital and emergency services [12]. Integrated Electronic Health Records (EHR) systems, which compile a comprehensive patient clinical record, have clear potential to significantly improve clinical care delivery by improving coordination of patient care across clinicians and delivery sites [13-21]. The 2009 stimulus bill allocated billions of dollars to promote meaningful use of EHR. In fact, the Department of Health and Human Services (DHHS) defined meaningful use to specifically target care coordination and healthcare quality [22, 23]. While EHR systems have been consistently promoted as a policy priority for improving the quality and efficiency of the American healthcare system, there is still limited research evidence to demonstrate this effect and to inform policy-makers about the role of EHR use on improving care coordination [18, 24].

Evidence suggests that care for patients with chronic diseases is best achieved when provided by high functioning multidisciplinary teams in primary care [2, 5, 20]. In addition, socio-technical theory proposes that the team environment is critical for the successful implementation of new technologies [25, 26]. The implementation of new technologies, such as EHRs, undoubtedly disrupts the team's clinical workflow and routines. There is documented variability on how successful clinical practices are at implementing EHR systems, where many are met with worker resistance with few resulting in noted failures [27]. While EHR systems vary in their level of usability, users also differ in their level of computer skills. There are likely many factors that contribute to the successful implementation of an EHR system.

All learning is achieved through both formal and informal channels. While formal learning is critical for instilling the basics of EHR use, informal learning, which is reinforced by communication and strength of working relationships may be even more critical to maximize the effectiveness of the new technology. Members working in teams with strong working relationships may be more comfortable experimenting with the different features available in the EHR through trial and error and may feel more encouraged to share best-practices learned with each other. This informal learning, which is facilitated through the strength of working relationships, could help clinicians learn how to leverage all of the tools available in the EHR in order to maximize any potential gains in quality while avoiding possible adverse outcomes.

For this study, I examined the association between EHR use and care coordination measures and how team working relationships modify this effect. I also examined the

effect of EHR use on clinical outcomes for patients with diabetes. I used existing primary care clinician team member survey responses, as well as the health system's comprehensive automated data collected over four years (2005-2009) while a large integrated delivery system in Northern California engaged in the staggered implementation of a new, certified EHR system. These analyses are divided into three research papers addressing the following main questions:

### **1. Connecting Clinicians: Use of Electronic Health Records and Care Coordination**

I examined the association between EHR use and care coordination. Specific questions included the following:

- Is use of a commercially available outpatient EHR, and an integrated outpatient-inpatient EHR associated with improvements in clinician reported measures of:
  - Coordination of care across clinicians?
  - Coordination of care across delivery sites?

### **2. Linking the Pieces Together: The Impact of Electronic Health Records and Teamwork on Care Transitions**

I examined the association between EHR use and reported measures of coordination for care transferred across delivery sites (e.g., from hospital to outpatient care) among teams with high and low reports of team cohesion, while adjusting for patient, physician, team, and medical center characteristics. Specific questions included the following:

- Does team cohesion modify the effect of use of an integrated outpatient-inpatient EHR on coordination of care across delivery sites?

### **3. The Impact of Electronic Health Records and Teamwork on Quality of Diabetes Care**

I examined the association between EHR use and clinical care quality for patients with diabetes receiving care from teams with high and low reports of team cohesion. This paper addressed the following research questions:

- Does team cohesion modify the effect of use of an outpatient EHR on physiologic measures of disease control for patients with diabetes including:
  - Glycosylated hemoglobin (HbA1c) values?
  - Low-density lipoprotein (LDL-C) values?

This study has several unique strengths: First, it leverages existing survey-based data that capture detailed measures of clinician reported care coordination and team cohesion at multiple points in time, as well as the health system's comprehensive automated databases. Second, the staggered nature of the EHR implementation allows

for adjustment of secular changes. This study provides important evidence on the role of EHR use on care coordination and quality improvement that are broadly applicable across the nation, especially given current policy efforts to promote meaningful use of EHR. In the current clinical environment, where care provided to patients is increasingly fragmented, and also increasingly complex, effective care coordination is essential. Health Information Technology, and specifically EHR, offer new opportunities for improving overall quality of care, preventing medical errors, and reducing health care costs. Also it is important to understand how the organization context of the team working environment influences the effect of EHR on care.

## **Background**

### **Definition of Study Terms**

#### **Electronic Health Records (EHR)**

In 2010 the Department of Health and Human Services (HHS) released specific criteria required for EHR systems to be certified as complete and thus potentially eligible for 'meaningful use' incentive payments [28]. A complete EHR must include the following: (1) computerized provider order entry (CPOE) for medications, laboratory, and radiology/imaging; (2) electronically transmit prescriptions; (3) record patient demographics; (3) generate patient reminder list for preventive and follow-up care; (4) clinical decision support; (5) electronic copy of patient's comprehensive clinical information; (6) timely access of patient's information at the point of care; (7) provide patients after visit summaries; (8) electronically transmit and receive clinical information; and (9) electronically calculate all quality measures specified by CMS [28]. The EHR is designed to completely replace paper-based medical charts and paper-based ordering of prescription medications and clinical laboratory tests.

#### **Quality**

The Institute of Medicine's (IOM) definition of quality is: "The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge [29]." This study examined outcome quality measures. Outcome refers to changes in patient health; examples include intermediate/physiologic measures such as lipid and HbA1c levels.

#### **Care Coordination**

The Stanford-UCSF Evidence-based Practice Center (EPC) published their final report in the series "Closing the Quality Gap", which focused on care coordination [9]. The authors reviewed over forty distinct definitions of the term and identified the following five key elements of care coordination:

1. Care coordination is necessary when two or more participants are involved in a patient's care
2. Participants are dependent on each other to carry out disparate activities related to the patient's care
3. Participants must be aware of each other's roles, responsibilities, and resources
4. Information exchange among participants required
5. Coordination has an agreed purpose or goal

#### **Primary Care Teamwork and Cohesion**

Studies show that particular attributes of the organizational work environment are associated with health outcomes [20, 30-35]. In particular, a number of studies found that clinician and staff characteristics, and more importantly, their interrelationships are associated with care quality [36-39]. In this study, I measured teamwork and cohesion using a previously validated survey instrument [40]. This instrument was specifically designed to measure relationships among team members that encourage communication and collaboration. High scores in this measure represent teams where members work together through open discussion to address and solve problems.

### **Increasing prevalence of patients with complex care needs and coordination challenges**

The number of Americans living with at least one chronic condition is large and growing. In 2005, almost half of all Americans had at least one chronic condition and one in four had multiple conditions [1, 2, 4]. Over two-thirds of Medicare dollars are spent on people living with five or more chronic conditions [30, 38]. These numbers are expected to rise sharply as the population continues to age. Any efforts to tackle the efficiency and quality of the American healthcare system will have to pay special attention to this growing population.

Patients with multiple chronic conditions typically see multiple providers and take numerous prescription drugs [31, 38]. Clinical management for these patients requires coordination between multiple physicians (e.g., primary care and specialists), sites of care (e.g., inpatient and outpatient), and treatments (e.g., drug regimens) across the health care system. In the current environment, where patient care is increasingly fragmented, effective care coordination is essential to ensure quality care [8, 11].

While patients with complex care needs face a higher clinical risk, evidence suggests that they are often receiving sub-optimal care [5, 10, 14-16, 21, 41-45]. Recent studies show that patients with multiple chronic conditions are more likely to experience an adverse drug event, and that the presence of one chronic condition decreased the likelihood that another condition would be treated [46, 47]. In addition, evidence indicates that clinicians rarely have access to complete medical information when patient care is transferred across providers and that patient safety may be jeopardized during transitions in care [5, 17, 43, 48-52].

Lack of timely information often results in inadequate patient monitoring, redundant care, medical errors, and greater use of services [53-57]. In a study of primary care clinics in Colorado, clinicians reported missing information in 14% of visits; 44% of these incidents were reported to adversely affect patients [48]. Patients with multiple chronic conditions were significantly more likely to have missing clinical information. Elder et al. reported that missing clinical information was associated with 15.6% of all reported errors in primary care [54, 55]. Evidence suggests that close collaboration between primary and specialty care results in improved health outcomes for the patient and more cost effective care [7, 56, 58, 59]. Lack of effective communication



across clinicians can result in disjointed and ineffective care [60-62]. One study reported that 18% of patients reported receiving conflicting information from various clinicians [63]. Any practical realization of a model for coordinated care must rely heavily on timely availability of comprehensive clinical information, likely provided through an integrated EHR system [57, 64].

While clinical guidelines have been developed to help in the treatment of patients with a single chronic condition, most fail to address the inherent complexities that exist in treating patients with multiple chronic conditions, where the recommended treatment for one condition may counteract the treatment of a second condition. Care coordination is especially important for patients with complex care needs who must manage multiple conditions, treatments, and clinicians. Without adequate coordination, patients may receive sub-optimal care with significant implications for their overall health and well-being.

### **Calls for Action: Health Information Technology and Care Coordination**

The IOM report on improving the delivery of health care in the United States, “Crossing the Quality Chasm: A New Health System for the 21<sup>st</sup> Century,” specifically targeted both coordination of care (across patient-conditions, types of medical services, and sites of care over time) and effective use of information technologies as top health system redesign imperatives [8]. The Patient Protection and Affordable Care Act of 2010 (PPACA) included several provisions specifically targeting care coordination through the use of Patient Centered Medical Homes (PCMH) and Accountable Care Organizations (ACO). Also, the 2009 stimulus bill allocated billions of dollars to promote the adoption and meaningful use of certified EHR systems [28, 65-67]. The HHS defined meaningful use to specifically target five health care goals, including care coordination and care quality [68]. While Health IT has been consistently promoted as a policy priority for improving the quality and efficiency of the American healthcare system, there is still limited research evidence to inform policy-makers about the effects of Health IT on care coordination. Better evidence of the benefits of EHR on all aspects of health care delivery, including care coordination, may help promote its adoption.

### **Potential for EHR to improve coordination of care**

Any practical realization of a model for coordinated care must rely heavily on timely access to comprehensive patient clinical information, likely provided through an integrated EHR system. Integrated EHR systems, which compile a comprehensive patient record and facilitate communication across clinicians and with patients, have clear potential to significantly improve care coordination and ultimately, clinical care delivery [69-74]. A key advantage of EHR over paper medical charts is the ability for multiple clinicians to reference the same patient record at the same time, often from different locations. This facilitates the use and quality of both formal and informal consultations. EHR use likely increases communication and shared information across

providers, allowing them to provide patients with a more cohesive, better coordinated care plan. While care coordination may be facilitated through the use of an EHR system, it is only one of many tools that clinicians can use to improve coordination, and EHR use is not synonymous with well-coordinated care [75]. Thus it is critical to examine the actual effects of an EHR system on care coordination, as well as the potential moderators of these effects.

In addition to supporting communication across clinicians, the use of consumer Health IT tools can also promote communication between patients and their providers and encourage patients to become more engaged in their healthcare decisions and self-care. There is evidence that use of patient portals result in improved patient-provider communication [76]. Previous research suggests that online access to their health records and providers improves patient satisfaction and increases communication with providers [77]. Patients with the option to email their provider also were more satisfied with the care they receive [78] and with the convenience of communicating with their provider remotely [79].

## **Care Coordination**

To properly study care coordination, we first need to define the concept. Without clear agreement on what constitutes care coordination it is impossible to measure it. Some measures of care coordination focus exclusively on the patient's perspective [7, 9, 80, 81]. However, in a recent article, Singer et al. distinguishes care coordination from care integration; while care integration is defined from the perspective of the patient, care coordination emphasizes the clinicians' point of view [75]. The authors state that while care integration emphasizes patient centeredness and the customization of care, coordination seeks efficiency and standardization. For this study, I chose to focus on the clinician's perspective and behavior. While the patient's perspective is also important, patients might not be fully aware of how well their care is being coordinated across clinicians and care delivery sites.

## **Teamwork**

Primary care in the United States is increasingly provided through the use of teams. In 2001, a seminal report from IOM called for a redesign of the American healthcare delivery system centered around primary care teams [8]. Many new and existing care models, such as ACOs, PCMH, and the chronic care model, continue to emphasize the vital role of teams in the provision of primary care. Multidisciplinary teams have been found to be especially important for managing the care of chronically ill patients [82-84]. Previous studies found that team care is associated with greater work satisfaction, perceived effectiveness, better clinical outcome measures, and patient satisfaction when compared with traditional non-team care [82, 85, 86]. The measure of team cohesion used in the existing KPNC clinician surveys derives from a measure developed in earlier research examining organizational attributes of primary care practices [40]. This study will focus on team climate instead of organizational culture

because of the assumption that climate is more applicable to the primary care team level.

### **KPNC and EHR - A Natural Experiment**

This study was conducted in Kaiser Permanente Northern California (KPNC), a large, prepaid integrated delivery system (IDS) providing comprehensive medical care for over three million members, including outpatient, inpatient, emergency department, pharmacy, and laboratory services. In February 2005, the IDS began a five-year staggered implementation of a commercially available, integrated EHR system certified by the Certification Commission for Health Information Technology (CCHIT) [28]. The EHR is an EpicCare®-based system that provides multiple new clinical functions including an electronic medical record (EMR), computer-based provider order entry (CPOE), decision support, and secure messaging across clinicians and patients.

The system was rolled out in two phases. Phase 1 (2005-2008) included the deployment of the system across its outpatient clinics, and phase 2 (2007-2010) across its hospitals. The EHR system was rolled out in the outpatient clinics, by medical center, and staggered by primary care team within each medical center. Once implemented, the EHR system completely replaced the paper-based medical record system.

In summary, EHR has great potential for improving care coordination, especially for patients with complex healthcare needs. This patient population is growing rapidly and the complexity of their care underscores the importance of timely, integrated clinical information to facilitate delivery of high quality coordinated care and improved outcomes. This study leverages existing data, including survey responses that capture detailed measures of clinician reported care coordination, teamwork, and cohesion at multiple points in time, as well as the substantial data resources from the study setting to explore the relationship between EHR use and teamwork on care coordination and quality. Lastly, the staggered nature of the EHR implementation allows for adjustment of secular changes.

## **Conceptual Framework**

The concept of coordination was first addressed in organizational theory by Lawrence and Lorsch in 1967. They asserted that environmental complexity determines the structural requirements of an organization, including coordinating activities [87]. Each subunit of the organization may have different levels of formalization, goal specificity, and centralization because it corresponds to a difference set of external demands. In their study, Lawrence and Lorsch interviewed executives from six chemical processing companies; their findings support a number of key propositions [87]. Organizations must properly balance differentiation and integration of sub-units to be well equipped to adapt to environmental changes. More task certainty lends itself to greater use of formal structures, whereas units faced with higher levels of uncertainty are better served by organic, less formal structures. Thus, Galbraith famously concluded that:

*“There is no one best organizational form and any way of organizing is not equally effective” [88].*

Galbraith defines uncertainty as the *“difference between the amount of information required to perform the task and the amount of information already possessed by the organization [88].”* To reduce task uncertainty, organizations can utilize a number of organizational designs, including; the creation of slack resources, self-contained tasks, and lateral relationships. An organization will choose the design which results in the least cost. The central question posed by contingency theory is: How should organizational structures be constructed to reflect overall level of complexity or uncertainty of the technology employed or work performed by the organization?

Adding to the theory, Thompson defined three types of task interdependence: pooled, sequential, and reciprocal [89]. Pooled interdependence is when there is little or no interaction among positions or sub-units, yet the overall organization remains viable. Each unit works separately to provide their small piece to the larger puzzle. When pooled independence is present, little or no coordination across sub-units is require to keep the organization viable. Sequential interdependence requires positions to adapt to action of another position further up on the line of action, such as in an assembly line. Sequential interdependence differs from reciprocal interdependence because each position must tailor its actions to more than one other actor in the organization. The output of one sub-unit becomes the input of a different sub-unit in a cyclical fashion. Reciprocal interdependence is complex and requires a high level of coordination, through constant information sharing and mutual adjustment.

Scott and Davis described several characteristics of Information Technologies. First, it allows for the rapid and accurate identification of problems and opportunities. Second, it increases the availability of relevant and timely information. Third, it uses feedback loops to transmit relevant information to appropriate decision centers and ultimately improves the speed and quality of decision making [90].

Health care delivery organizations, at their core, provide information intensive services. A task in the provision of medical care can be defined as clinical decisions regarding the patient. Task uncertainty can be interpreted as clinicians' timely access to all of the relevant information necessary when making critical clinical decisions regarding their patient. Generally, more specialization leads to greater fragmentation of information. Patients with chronic conditions who require specialized care from multiple providers likely face higher task uncertainty. Thus, in a health care system where patient care is increasingly fragmented, use of integrated EHR systems may be crucial for reducing task uncertainty, by facilitating the transfer of relevant information and communication across clinicians, thus allowing for greater use of care coordination activities, and ultimately resulting in improvements in care quality and patient health outcomes.

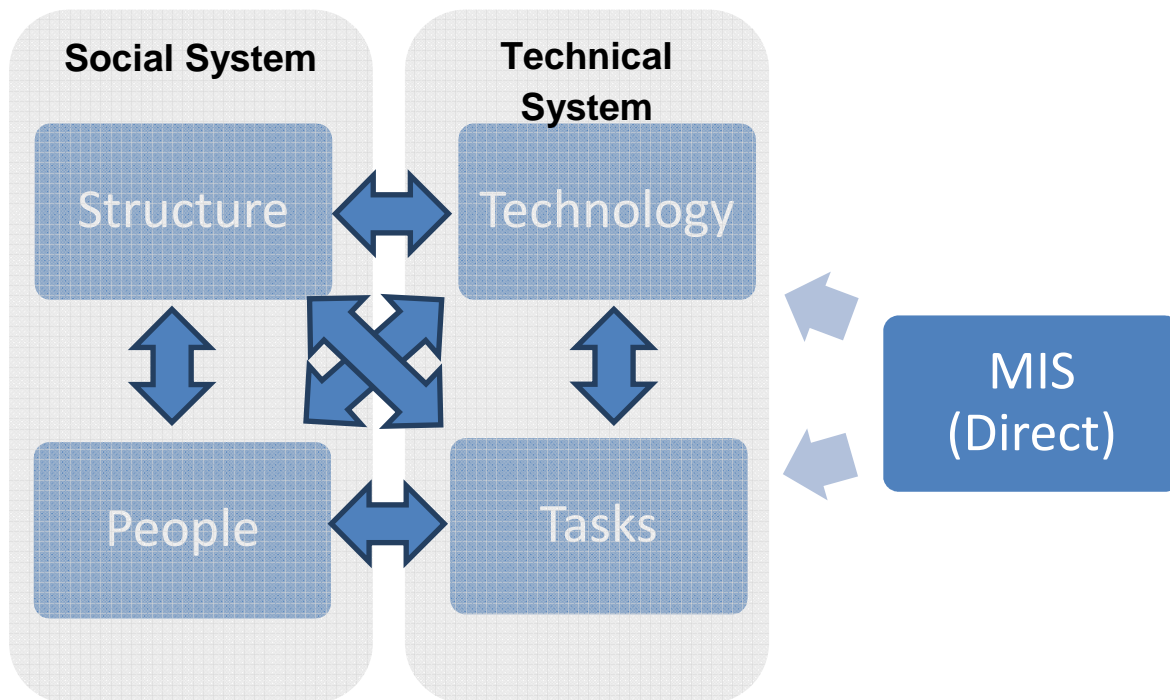
Clinicians must often adapt their treatment plan based on the care and guidance of other clinicians involved in their patient's care. In order to provide the patient with a cohesive and appropriate treatment plan, while minimizing avoidable errors, clinicians need to constantly share information and mutually adjust their actions. Therefore, medical care for patients with complex healthcare needs is best characterized by reciprocal interdependence and thus requires a high level of coordination. The type of interdependence is driven by the patient's characteristic and the specific nature of the care being provided.

In general, it is easy to conclude that an information system based on paper medical charts does not adequately reflect the complexity of work performed by health care delivery organizations. EHR systems, which facilitate the constant sharing of relevant information and communication across clinicians, may reduce task uncertainty and allow clinicians to match coordination activities to the needs of their patients. Galbraith outlined several coordination mechanisms, such as rules and formalized procedures, standardization, hierarchy, and cohesive and precise goals that firms can use to improve performance once uncertainty is minimized.

By providing clinicians timely access to patients' comprehensive clinical records, the EHR may reduce task uncertainty and allow for greater use of coordinating activities, such as standardization or care and more precise goals for patients whose care is characterized by sequential interdependence. For those patients whose care is characterized by reciprocal interdependence, the EHR may provide clinicians with a more efficient mechanism to communicate with each other and the patient, thus facilitating frequent contact which is needed for each party to appropriately adjust each other's actions.

Contingency theory suggests that use of EHR systems may be a better technical fit than paper-based charts for the provision on complex healthcare tasks, ultimately resulting in improved outcomes for patients. Socio-technical theory states that both the technical and human systems need to be considered jointly in order to maximize outcomes [91]. The theory also emphasizes the role of work groups in providing incentives, learning opportunities, and social support.

**Figure 1: Socio-technical framework**



Note: Figure adapted from Bostrom, R.P. and J.S. Heinen, *MIS problems and failures: a socio-technical perspective, part II: the application of socio-technical theory*. MIS quarterly, 1977: p. 11-28.

MIS=Management Information System

The socio-technical framework recognizes the importance of optimizing the interaction between social and technical environments (figure 1). The technical system represents the individual tasks and technology required to transform inputs into outputs. The Social system represents the human aspects of the organization, the people, including their values, attitudes, and skill, relationships with each other, and management, including reward structures and leadership [91, 92]. Changes in technology will inevitable cause changes in other variables in the system, such as task structures, routines, and work relationships. The social and technical systems should be designed to complement each other. A recent paper outlined several ways in which the social environment can interact with EHR implementation resulting in many unintended and undesirable consequences [92]. Examples include, busy clinicians entering critical data in miscellaneous sections of the EHR, making it difficult for others to retrieve, and the EHR eliminating the need for frequent informal interactions, which previously provided redundant checks that helped prevent errors. When assessing the impact of a new information system on any outcome, it is critical to consider the implications of the organizational and social environment [91, 92].

In this study, the technical environment is represented by the EHR, which inherently causes significant disruptions to primary care teams' clinical workflow. Although there are many aspects of the work environment that could modify the effectiveness of the EHR to improve clinical care, including leadership and culture, for this study, I focus on

the strength of working relationships within primary care teams. I chose to focus on team relationships for several reasons. First, the use of teams in the provision of primary care has been steadily increasing. Many models of care delivery, such as ACOs, PCMH, and the chronic care model, emphasize the central role of multidisciplinary primary care teams in improving care quality and outcomes, especially for patients with chronic conditions [82-84]. Lastly, there is a growing body of research confirming that team care is indeed associated with improved care quality and outcomes [82, 85, 86].

Although use of EHR can clearly function to reduce task uncertainty by providing clinicians with complete and accurate information at the point of care, clinicians first need to learn to effectively use this new technology. Evidence suggests that care for patients with chronic diseases is optimized when provided by high functioning multidisciplinary teams in primary care [2, 5, 20]. In addition, socio-technical theory states that the team environment is critical for the successful implementation of new technologies [25, 26, 91]. The implementation of new technology, such as EHR, undoubtedly disrupts the team's clinical workflow and routines. Primary care teams need to work together to adjust to the inevitable changes brought on by the EHR.

There is documented variability on how successful clinical practices are at implementing EHR systems, where some have been met with worker resistance and few resulted in noted failures [27]. While EHR systems vary in their degree of usability, users also differ in their level of computer skills. There are likely many factors that contribute to the successful implementation of an EHR system. Not all EHR systems and organizational structures will result in the same level of improvements in care quality from the EHR, and some may even result in greater inefficiencies and adverse outcomes.

It is important to realize the limitation of EHR system in bringing about improvements in care. EHR implementation will not automatically result in improvements in care quality and efficiency, and in fact may have the opposite effect if not used properly. For example, at KPNC, shortly after the EHR implementation, many primary care clinicians reported being overwhelmed by the amount of information available, resulting in inefficiencies. For example, one clinician stated:

*“There is so much information and repetition in the system. It's easy to miss the important points.”*

In addition, clinicians may enter critical data in miscellaneous sections of the EHR, making it difficult for others to retrieve. Use of the EHR could be eliminating the need for frequent informal interactions between team members, which previously provided redundant checks that helped prevent errors. Also, extensive reporting requirements combined with limited time, may cause clinicians to cut and paste irrelevant and possibly outdated information in the patients record.

Effective learning on how to use the system is critical to not only maximize gains in quality of care, but could also help clinicians avoid any potential adverse outcome from the EHR. Learning is achieved through both formal and informal channels. While formal learning is critical for instilling the basics of EHR use, informal learning, which is

reinforced by communication and strength of working relationships, may be even more important to maximize the effectiveness of the new technology [26]. Members working in teams with strong working relationships may feel more comfortable experimenting with the new technology through trial and error and may be more encouraged to share best-practices learned with each other.

Even though all primary care clinicians working at KPNC received equivalent classroom style formal training on the basics of EHR use, when asked how they learned to use the system, almost all cited informal learning channels. For example, primary care clinicians said:

*“Colleagues taught me more [on how to use EHRs] than formal presentations.”*

*“[I learned to use EHRs] mostly by practicing, trying to solve problems, talking to other people, and a lot of trial and error.”*

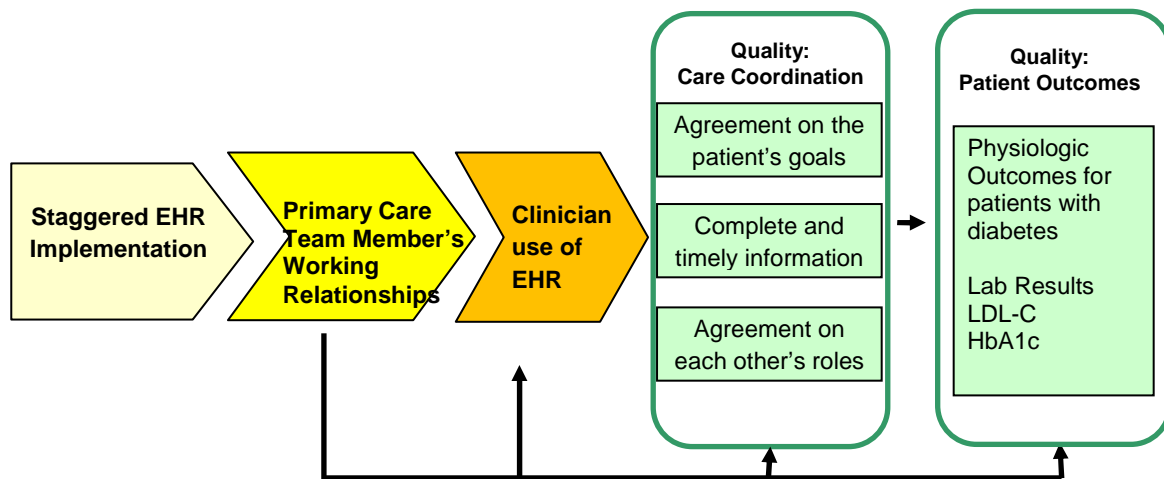
Informal learning may be critical to speed the collective learning process of this new technology and ensure that clinicians maximize the potential benefits of the EHR while avoiding possible harmful effects.

In conclusion, organizations must match their structural capabilities to the complexity of their tasks and environmental conditions. Medical care for patients with complex healthcare needs is characterized by reciprocal interdependence which requires a high level of coordination in order to be successful. Coordinating activities are limited in the presence of task uncertainty. Health IT should reduce uncertainty by facilitating the transfer of information across clinicians and sites of care and thus allow clinicians to increase use of formal and informal coordinating activities. Also, strong working relationships among primary care team members may facilitate informal collective learning on how to use the EHR resulting in greater benefits.

The conceptual framework for this study is depicted in figure 2. In this framework, I propose that relationships among primary care team members with EHR use will moderate how individual clinicians actually use the range of EHR functions available to them, thus moderating their overall impact on care coordination and care quality for patients with diabetes. While I expect that EHR use will result in direct benefits to care coordination and quality measures, teams with strong teamwork and cohesion scores may more successfully leverage the available EHR functions, resulting in even greater improvements in these outcomes.



**Figure 2. Conceptual Framework**



## Hypotheses

My conceptual model posits that EHR use will improve overall care coordination and care quality, and that this association will vary by working relationships among primary care team members. Additionally, I expect improvements in care coordination to result in higher care quality.

The specific study hypotheses are the following:

- EHR use is associated with higher levels of reported care coordination
  - This association will vary by teamwork and cohesion and will be stronger for teams with higher team cohesion scores
  - Care coordination will be associated with clinical care for patients with diabetes
- EHR use is associated with improved clinical outcomes for patients with diabetes
  - This association will vary by teamwork and cohesion, and will be stronger for teams with higher team cohesion scores

## **Research Design Overview**

For this study, I examined the association between EHR use and care coordination measures, and how team working relationships modify the effect of EHR use on reported measures of care coordination and clinical outcomes for patients with diabetes. I used existing primary care clinician survey responses, collected as part of the AHRQ sponsored R01 IMPACT study, as well as the health system's automated data collected over four years (2005-2009) while a large IDS in Northern California engaged in the staggered implementation of a new, certified EHR system.

I analyzed quasi-experimental changes in exposure to EHR across a staggered implementation in inpatient and outpatient settings during 2005-2009, using a pre-post analytic design with concurrent controls (Figure 2). This study will use primary care clinician surveys collected in 2005, 2006, and 2008 and the longitudinal experience of patients within an IDS. Care coordination and teamwork and cohesion will be captured using existing self-administered clinician survey responses, including measures collected before and after the EHR was launched. Quality and clinical outcome measures for patients with diabetes will be derived from the system's automated databases and will include physiologic disease control (measured by laboratory tests) for patients with diabetes.

This study leverages data collected from previous related work and the substantial data resources of the study setting. The IDS's pre-EHR automated databases capture patient quality and clinical outcome data consistently throughout the study period. To examine the impact of EHR use on care coordination, I evaluated clinician reported measures of care coordination collected over three years while the IDS was implementing a certified outpatient-inpatient EHR system. To evaluate the association between EHR and teamwork on clinical care for patients with diabetes, I will examine guideline-consistent lab results (e.g., HbA1c and LDL levels) using the IDS's automated clinical data. These measures represent areas for which the IDS has clinical guidelines and consistent capture of patient data, and where significant room for improvement exists. These are considered standard physiologic measures of disease control for patients with diabetes.

This study has several unique strengths:

- The IDS provides a large sample of primary care clinicians and patients yielding adequate statistical power to detect differences in relatively rare events in the evaluation of clinical quality.
- The population is both stable and well-defined, with an average of 5% turnover from year to year.
- The analyses will adjust for a wide range of individual patient, insurance, and structural covariates using existing data sources
- The study leverages existing survey-based data that capture detailed measures of clinician reported care coordination and team climate at multiple points in time
- The staggered EHR implementation allows for adjustment for secular changes (concurrent controls).

## **Study Setting – Kaiser Permanente Northern California**

This study was conducted in Kaiser Permanente Northern California (KPNC), a large, prepaid Integrated Delivery System (IDS) providing comprehensive medical care for over three million members, including outpatient, inpatient, emergency department, pharmacy, and laboratory services. The IDS provides care for over two million adult members and has over 1,000 adult primary care clinicians in the Internal Medicine and Family Medicine departments, grouped in 110 primary care teams across 18 medical centers.

## **Population**

Survey data on teamwork and coordination used in this study was collected from all adult primary care team members working at KPNC, including physicians, nurse practitioners, and physician's assistants. Primary care team member survey responses were linked with patient panels using the health system's automated databases. Since patients with complex health care needs are likely to benefit most from improvements in care coordination, this study focused on patients with diabetes. The study population included IDS members who were in the healthplan diabetes clinical registry as of the last quarter of 2003. I then used IDS administrative data to link patients with a single primary care team and excluded members who had changes in their primary care team linkage during the study period (1/2005-12/2009). In addition, members left the study cohort when they first dis-enrolled from the IDS (average 4.9% per year) or died (2.6% per year).

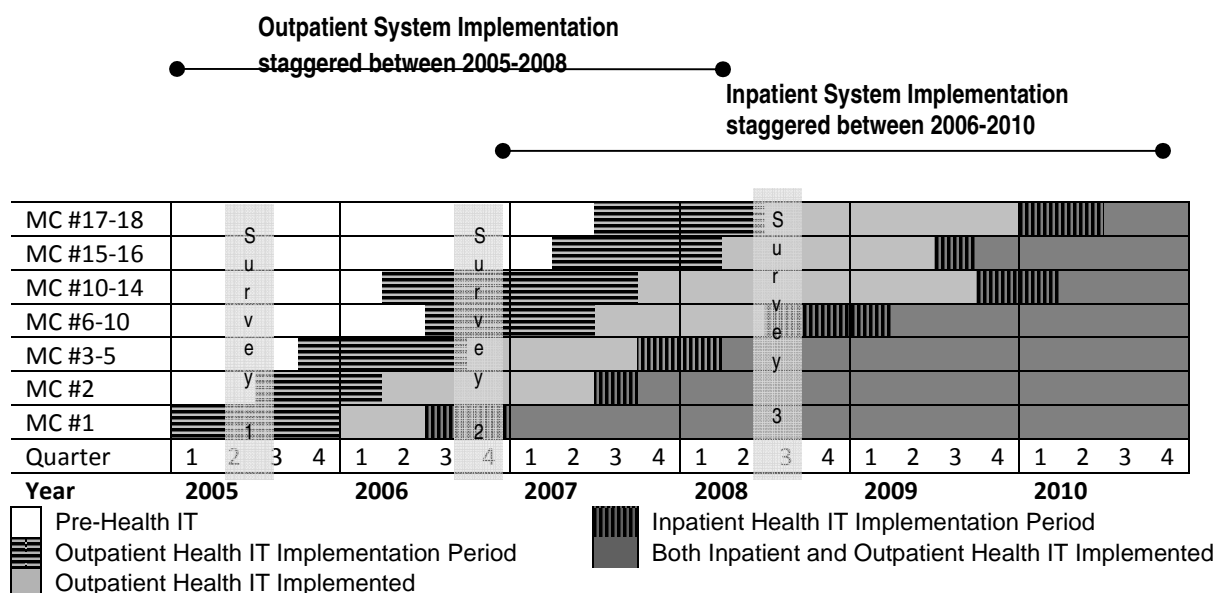
## **Survey Collection**

In 2005, 2006, and 2008 we mailed a self-administered questionnaire to all adult primary care team members working at KPNC (IMPACT survey). Each clinician received a letter introducing the study, a copy of the survey, and a pre-paid return envelope. Respondents who completed the survey received a small gift card. Non-respondents were sent reminder letters and additional copies of the surveys; up to four follow-up mailings were sent during each year of survey collection. The Institutional Review Boards of the Kaiser Foundation Research Institute and UC Berkeley approved the study protocol and materials.

Overall, 565 primary care clinicians responded in 2005 (48% response rate), 678 in 2006 (62% response rate), and 626 in 2008 (61% response rate). Figure 2 shows a collapsed version of the staggered integrated EHR implementation schedule and survey collection. The full implementation was staggered by medical center, and by clinic within medical center (with approximately a 3-week lag between clinics within given medical centers). The survey was collected in three waves: first, in 2005, during the early stages

of the EHR implementation, when few clinicians had access to the new EHR system; then in 2006, roughly midway through the outpatient EHR implementation process; and finally in 2008, after all outpatient clinics had finished implementing the outpatient component and roughly half of the hospitals had completed the implementation of the inpatient EHR.

**Figure 2. Quasi-experimental Study: Staggered Implementation of Integrated Health IT Across Medical Centers**



Note: The actual implementation schedule has different specific staggered start and stop dates for all 18 medical centers. We collapsed this detailed schedule into the figure above.

### Survey Instrument

On the survey, we asked primary care clinicians about four specific aspects of care coordination when patient care is transferred across clinicians (e.g. from a specialist to the primary care team) and across delivery sites (e.g., from the hospital to the outpatient team). We asked clinicians how often does each of the following occur: (1) “all relevant medical information is available”; (2) “the information transfer is timely, i.e. available when it is needed”; (3) “all clinicians agree on the treatment goals and plans”; and (4) “all clinicians agree on roles and responsibilities of each party.” The response categories were: never, rarely, sometimes, usually, and always.

The survey also included 16 previously validated questions on team climate.<sup>12</sup> This scale addressed the following five dimensions: (1) conflict resolution (e.g., “When there is conflict in this team, the people involved usually talk it out and resolve the problem successfully”); (2) working relationships (e.g., “The team members operate as a real team”); (3) leadership and decision-making approaches (e.g., “All team members participate in important decisions about the clinical operation.”); (4) stress (e.g., “Working in the team is stressful”); and (5) quality improvement efforts (e.g., “Team members are involved in developing plans or improving quality”). Each item was scored on a one to five scale (“strongly disagree”...“strongly agree”).

## **Automated Data**

The Kaiser Permanente administrative databases will be used to assess clinicians' use of the integrated EHR system and to obtain specific clinician characteristics, including age, gender, job title, and race/ethnicity. It will also be used to link clinicians to patients in their care. The primary outcome measures of clinical care quality are patient lab results for HbA1c and LDL-C.

## **Analysis Approach**

The analytic approach allows for separation of EHR and care coordination effects from concurrent background secular changes, while accommodating the staggered introduction of the EHR system across clinics within the medical centers. I used repeated measure outcome data obtained from clinician surveys collected in 2005, 2006, and 2008 and patient outcomes captured over the same period using the automated databases.

The models include terms to represent the concurrent secular trend using dummy variables to represent each year covered in the study. By modeling secular trends in this way, I can estimate the EHR effects over and above the effect of the background time changes. My approaches will account for clustering in the repeated outcome data at multiple levels in the care hierarchy: medical center (which contain each hospital), team, clinician, and patient. I will handle the medical centers as fixed effects, using indicator variables for each center. The other clustering levels will be accounted for using either random or fixed effects or by aggregation to a higher level by summing over units at lower levels. In some situations, covariates defined for higher level units will explain enough of the variability at that level so that models with random effects are no longer needed to account for the small amount of remaining unit-to-unit variability at that level; I assess the amount of variability at each level for all analyses.

I considered using generalized estimating equation (GEE) and generalized linear mixed model (GLMM) modeling approaches to adjust for repeated clinician observations and the hierarchical nature of the data. All models will be adjusted secular time trends, and when appropriate, will include medical center dummy variables to account for organizational differences and clustering by primary care team. A GEE approach should provide an overall view of the averaged population association between EHR and measures of care coordination controlling for a number of variables. The GLMM family can handle binary outcome data and also count data. This fixed-effects estimation approach has good large-sample properties (e.g. consistency). It also deals with two of the features of the data: multi-level structure and potential unmeasured confounders due to selection.

## **CHAPTER 2: CONNECTING CLINICIANS - USE OF ELECTRONIC HEALTH RECORDS AND CARE COORDINATION**

## ABSTRACT

**Objective.** Evidence suggests that patient care may be jeopardized during transitions in care. Electronic Health Record (EHR) has the potential to significantly improve care transitions by increasing the availability and timeliness of clinical information and providing clinicians with tools to improve communication. I exploit variations across the timing of the implementation of a commercially available outpatient and inpatient EHR system over 18 Medical Centers to examine the impact of the EHR on care coordination measures using a quasi-experimental pre-post design with concurrent controls.

**Study Design/Data Collection.** Surveys of all primary care clinicians were collected over three years during the staggered implementation of an EHR. Response rates were 48.1% (N=565) in 2005, 61.5% (N=678) in 2006, and 60.8% (N=626) in 2008. Using multivariate logistic regression to adjust for clinician characteristics, medical center, and time, I examined the impact of EHR use on three dimensions of coordination of care transferred across clinicians and across delivery sites: access to complete and timely information; treatment goal agreement; and role/responsibility agreement. I categorized EHR status into three stages: No EHR, outpatient EHR only, and integrated outpatient-inpatient EHR.

**Principal Findings.** In adjusted analyses, I found that use of the outpatient EHR alone was associated with improvements in reported care coordination across clinicians for access to timely and complete information and clinician agreement on the patients' treatment plan, but not with care coordination across delivery sites. Use of the integrated outpatient-inpatient EHR was associated with significant improvements in care coordination across delivery sites and across clinicians.

**Conclusion.** Electronic Health Records is an important tool for improving care coordination across clinicians and delivery sites. These improvements may result in significant increases in the overall quality of care. However, use of stand-alone, non-integrated EHR systems may not improve care coordination across delivery sites.

## Introduction

The number of Americans living with chronic conditions is large and growing [1, 2]. Clinical management of these patients often requires coordination between multiple physicians and sites of care [1-4]. The implementation of an Electronic Health Record (EHR) could be key in facilitating the transfer of information and improving coordination of patient care across multiple clinicians and sites of care [5, 16, 18, 21, 93]. While EHR has been consistently promoted as a policy priority for improving the quality and efficiency of the American healthcare system, there is still limited research evidence to inform policy-makers about the effects of EHR on care coordination [16, 18, 24, 67, 94, 95].

Integrated EHR systems, which compile a comprehensive patient clinical record, have the potential to significantly improve clinical care delivery by improving the availability and timeliness of patient's medical information [69-74, 96]. In addition, comprehensive EHR systems provide clinicians with a mechanism to effectively communicate with all providers involved in a patient's care. Existing evidence indicates that clinicians rarely have access to complete medical information when patient care is transferred across delivery sites and that patient safety may be jeopardized during these transitions in care [5, 17, 49, 50]. Elder et al. reported that missing clinical information was associated with 15.6% of all reported errors in primary care [55]. Lack of timely information often results in inadequate patient monitoring, redundant care, medical errors, and greater use of hospital and emergency services [52, 54-57]. Ineffective communication across clinicians may also result in a number of adverse events [52, 60-63, 97]. One study found that patients with chronic conditions often report receiving conflicting information from providers [63].

Use of an EHR may increase communication and shared information across providers, allowing them to provide patients with a more cohesive, better coordinated care plan. The transfer of patients across clinicians and delivery sites has been shown to increase the risk of medical errors, whereas efforts to coordinate care delivery have resulted in improvements in safety [98]. Poorly executed care transitions can lead to greater use of hospital, emergency and ambulatory services. Coordinated transitions require the timely transfer of patient data, as well as clinician agreement on the patient's treatment plan and each other's roles and responsibilities.

Despite the many potential benefits associated with use of EHR, use of such systems remains astoundingly low. As of 2009, nearly four out of five outpatient physicians did not have access to EHRs [99-101]. To address low EHR adoption, the American Recovery and Reinvestment Act of 2009 allocated \$27 billion to encourage adoption and meaningful use of Health IT in the United States by 2014 [23, 28, 67, 95]. Communication of clinical information, for care coordination is explicitly listed as a requirement for "meaningful use" of EHR under ARRA [102]. A major way in which EHR is expected to improve care quality and efficiency is through

To examine the effects of EHR use on care coordination during transfers of care across clinicians and sites, we collected surveys from primary care clinicians over three years (2005, 2006, and 2008), during the staggered implementation of a commercially



available, integrated EHR system. In this study, we examined whether various clinician reported measures of care coordination were associated with EHR use.

## **METHODS**

### **Study Setting**

This study was conducted in Kaiser Permanente Northern California (KPNC), a large, prepaid Integrated Delivery System (IDS) providing comprehensive medical care for over three million members. Adult primary care clinicians worked in the Internal Medicine and Family Medicine departments and were grouped in 110 primary care teams, across 18 Medical Centers.

### **Health Information Technology**

In 2010 the Department of Health and Human Services (HHS) released specific criteria required for EHR systems to be certified as complete and thus potentially eligible 'meaningful use' incentive payments [28]. A complete EHR must include the following functions: (1) computerized provider order entry (CPOE) for medications, laboratory, and radiology/imaging; (2) electronically transmit prescriptions; (3) record patient demographics; (3) generate patient reminder list for preventive and follow-up care; (4) clinical decision support; (5) electronic copy of patient's comprehensive clinical information; (6) timely access of patient's information at the point of care; (7) provide patients after summaries for each visit; (8) electronically transmit and receive clinical information; and (9) electronically calculate all quality measures specified by CMS [28]. The EHR is designed to completely replace paper-based medical charts and paper-based ordering of prescription medications and clinical laboratory tests.

In February 2005, the IDS began a five-year staggered implementation of a commercially available, integrated outpatient-inpatient certified-EHR system. The system was rolled out in two phases: staggered deployment of the system across outpatient clinics (2005-2007), and staggered deployment across inpatient hospitals (2007-2010). For implementation across outpatient clinics, the EHR system was installed by medical center, and staggered by primary care team within each medical center. Medical centers typically implemented the inpatient EHR system about one year after the outpatient clinic. Once implemented, use of the EHR system was mandatory.

Prior to the deployment of the integrated EHR system in early 2005, there was already a patchwork of non-integrated Health IT applications available to clinicians working in the IDS. While these earlier applications provided some helpful functions, they were not integrated with each other, meaning that the provider had to log onto each application separately, and information was not automatically updated from one application to the next. Use of these early Health IT functions was voluntary, as paper-based medical charts and paper-based alternatives for completing many of the same functions were still in use.

## Survey Collection

In 2005, 2006, and 2008 we mailed a self-administered questionnaire to all adult primary care clinicians working in the IDS, including physicians (MD or DO), nurse practitioners, and physician's assistants. We excluded clinicians who did not have an active panel of patients at the time of the survey. Each clinician received a letter introducing the study, a copy of the survey, and a pre-paid return envelope. Respondents who completed the survey received a small gift card. Non-respondents were re-sent reminder letters and surveys; up to four follow-up mailings were sent during each year of survey collection.

The study population included 1,175 clinicians in 2005; 1,103 clinicians in 2006; and 1,030 clinicians in 2008. Overall, 565 primary care clinicians responded in 2005 (48% response rate), 678 in 2006 (62% response rate), and 626 in 2008 (61% response rate).

## Survey Instrument

On the survey, we asked care coordination questions about two care transition situations: when patient care is transferred across clinicians (e.g. from a specialist to the primary care team) and when care is transferred across delivery sites (e.g., from the hospital to the outpatient team).

For each care transition situation, we asked four specific aspects of care coordination, asking: "How often does each of the following occur?"

1. "All relevant medical information is available."
2. "The information transfer is timely, i.e. available when it is needed."
3. "All clinicians agree on the treatment goals and plans."
4. "All clinicians agree on roles and responsibilities of each party."

The response categories were: never, rarely, sometimes, usually, and always. Questions on care coordination were developed by an expert panel of scientific advisors specifically for this study. In addition, the survey collected several respondent characteristics, including race/ethnicity, gender, job title, and hours worked per week. We supplemented survey responses with information attained from the IDS' automated database on certain PCP characteristics, including age, gender, job title, and race/ethnicity.

## Data Analysis

### Outcome measures

We examined three outcome measures of care coordination for care transferred across clinicians and across delivery sites. First, we combined responses to the survey questions asking if 'all relevant medical information is available' and if 'information transfer is timely'. We reasoned that in order for information to be useful when coordinating care, it must be both complete and timely. In addition, responses to the two

original survey questions were highly correlated (0.8). We created a dichotomous outcome measure, 'Access to complete and timely information'. This variable was coded as one if the respondent reported 'always' or 'usually' to both questions, otherwise it was coded as zero.

For the other two coordination measures, we created two separate dichotomous variables called "agreement on treatment goals and plans" and "agreement on roles and responsibilities"; each was coded as one if to the clinician responded that the relevant agreement 'always' or 'usually' occurs, otherwise it was coded as a zero. The number of missing values was small (<5%) and not correlated with EHR status, therefore missing responses were dropped from the analyses.

## Predictor measures

The independent variable of interest was use of the integrated EHR. For outpatient EHR, we defined EHR use using the IDS' automated data, which captured the source of diagnoses (pre-EHR data system vs. EHR). Since availability of EHR may have varied during the installation transition period, we defined clinicians as having access to EHR when over 80 percent of visits made by their primary care team were entered using the EHR system (typically within a month of initial installation). For the inpatient EHR, we used the implementation schedule which provided that exact date when the integrated EHR system went live at each hospital.

We categorized three stages of EHR adoption; not available, available at the outpatient clinic, and available at both the outpatient and inpatient delivery sites. We defined each primary care clinician's integrated EHR status at the date they completed the survey based on their team and hospital's EHR status.

## Model

To analyze the effect of using an integrated EHR system on our three measures of coordination of care, we used a generalized estimating equation (GEE) model to adjust for repeated clinician observations. A GEE approach provided an overall view of the averaged population association between EHR and measures of care coordination controlling for a number of variables. I included the following clinician characteristics as covariates: age, gender, race/ethnicity, job title, and weekly hours worked. I also included a year indicator variable to control for time trends that may have affected the dependent variables but were unrelated to the implementation of EHR. In addition, I included indicator variables for each medical center to control for medical center specific fixed effects. The models presented provide an overall view of the averaged effects of EHR on the measures of care coordination controlling for a number of variables.

$$\text{Equation 1: } \text{Logit} [P(Y_{it}=1|X_{it} = x_{it})] = \beta_0 + \beta_1 dEHRImpl_{it} + \beta_2 dYear_{it} + \beta_3 dAge_{it} + \beta_4 dFemale + \beta_5 dWhite_{it} + \beta_6 dPhysician_{it} + \beta_7 dFulltime_{it} + \beta_8 dMC_{it} + u_{it} + a_i$$

Y represents the binary dependent variables for each care coordination outcome. In equation (1), I specify three variables within EHRImpl vector to allow for different effects for the three stages of implementation, no-EHR, outpatient EHR only, and integrated outpatient-inpatient EHR. The main parameters of interest are the coefficients for outpatient EHR only and integrated outpatient-inpatient EHR within the  $\beta_1$  vector. Year effect is included to account secular changes in the outcome variable that may be unrelated to use of EHR, such as new protocols for charting. I will also include medical center fixed effects to control for any cross-sectional correlations between reported availability and timeliness of information and EHR implementation status. Additionally, I will include individual primary care clinician characteristics, such as age, gender, race/ethnicity, job title, and job status (full time vs. part time). Some of these characteristics are time invariant and others, such as fulltime status and age may change over time.

## Results

Table 1 shows the characteristics of respondents who completed the survey in 2005, 2006, and 2008. In 2005, most respondents (93%) were not yet using the EHR system; by 2006, only 26% of respondents were not using EHR, 68% were using outpatient EHR, and 6% worked in medical centers that had implemented both outpatient and inpatient EHR; in 2008, all primary care clinicians had started using the outpatient EHR and 50% worked in medical centers with both outpatient and inpatient EHR.

Table 1: Respondent characteristics by survey year

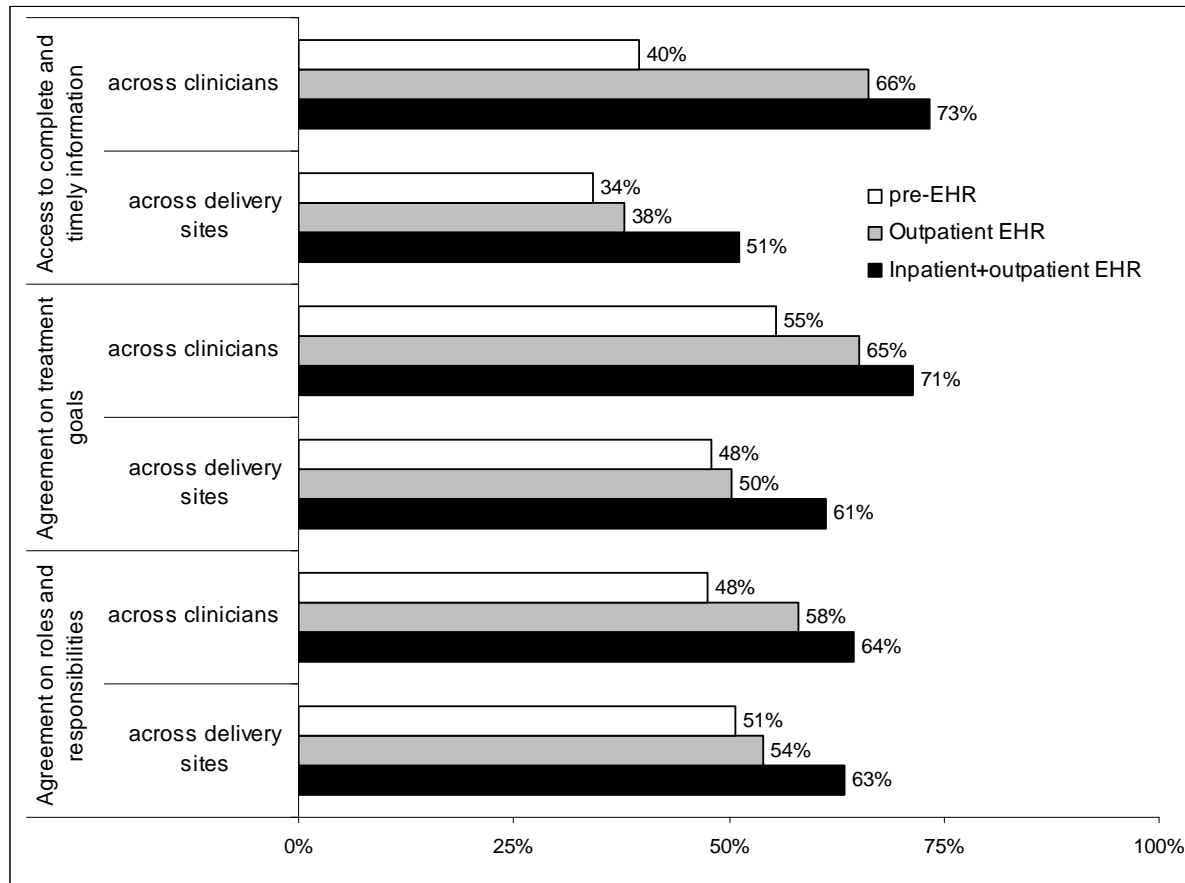
	2005		2006		2008	
	Respondent (N=565)	Eligible (N=1175)	Respondent (N=678)	Eligible (N=1103)	Respondent (N=626)	Eligible (N=1030)
<b>%</b>						
<b>Response Rate</b>	48.1		61.5		60.8	
<b>Gender:</b> Female	54.8	48.8*	54.4	48.8*	52.1	50.6
Male	45.2	51.2	45.6	51.8	47.9	49.4
<b>Race/Ethnicity:</b> White	48.1	49.0	42.4	44.2	38.8	38.4
Non-white	51.9	51.9	57.6	55.8	61.2	61.6
<b>Job Title:</b> M.D./D.O.	84.2	88.9*	88.4	90.3*	93.1	94.1
N.P/P.A.	15.8	11.1	11.7	9.7	6.9	5.9
<b>Age:</b> <40	36.0	35.6	38.1	35.1*	39.6	35.6*
41-50	32.5	32.3	32.0	33.2	33.7	35.6
51+	31.4	32.1	29.9	31.8	26.7	26.7
<b>EHR Status:</b> No EHR	92.9	94.9*	25.8	27.3	0.0	0.0
Phase1: outpatient	7.1	5.1	67.9	67.0	50.3	50.7
Phase2: outpatient + inpatient	0.0	0.0	6.3	5.7	49.7	49.3

\*Indicates p-value<0.05 comparing differences between respondents and the total eligible population in each year of data collection. Overall, 262 clinicians completed the survey in all three waves of data collection (2005, 2006, and 2008), 609 completed at least two rounds of surveys, and 1,207 clinicians completed at least one survey.

Overall, as EHR was implemented, there were consistent increases in clinician's reports of care coordination across clinicians and delivery sites (all  $p < .005$ ) (Figure 1). For care transitions across clinicians (e.g. from a specialist to the primary care team), 40% of clinicians without EHR reported having access to complete and timely information compared to 66% of clinicians with outpatient EHR, and 73% of clinicians with both inpatient and outpatient EHR; 55% of clinicians without EHR reported agreement on treatment goals and plans, compared to 65% and 71% of clinicians with just outpatient EHR and both inpatient and outpatient EHR respectively; and 48% of clinicians without EHR reported agreement on roles and responsibilities compared to 58% and 64% of clinicians with just outpatient EHR and both inpatient and outpatient EHR respectively.

Clinician reported care coordination for transitions across delivery sites were generally lower than for transitions across clinicians (Figure 1). For care transitions across delivery sites (e.g., from the hospital to the outpatient team), 34% of clinicians without EHR reported access to complete and timely information, compared to 38% and 51% of clinicians with just outpatient EHR and both inpatient and outpatient EHR respectively; 48% of clinicians without EHR reported agreement on treatment goals and plans, compared to 50% and 61% of clinicians with just outpatient EHR and both inpatient and outpatient EHR respectively; and 51% of clinicians without EHR reported agreement on roles and responsibilities compared to 54% and 63% of clinicians with just outpatient EHR and both inpatient and outpatient EHR respectively.

**Figure 1: Unadjusted Clinician reported high levels of care coordination by EHR Status**



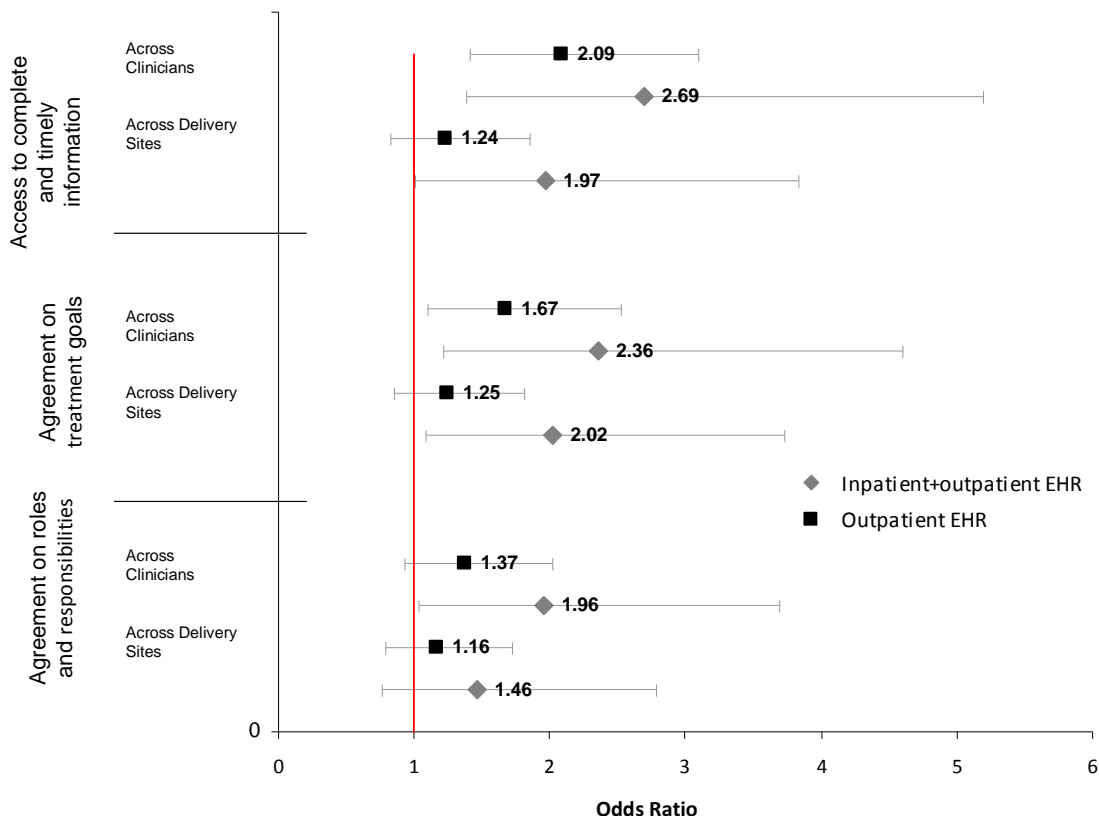
Note: Figure displays the percentage of respondents who reported that the coordination outcome always or usually occurs when patient care is transferred across clinicians and across delivery sites; data are unadjusted for clinician characteristics and time trends.

Figure 2 displays the results of the adjusted multivariate logistic regression analyses of each of the three coordination measures for care transferred across clinicians and across delivery sites. For care transferred across clinicians, clinicians with access to only outpatient EHR were significantly more likely to report access to timely and complete information (OR=2.09, 95% CI: 1.41-3.09) and clinician agreement on treatment goals and plans (OR=1.67, 95% CI: 1.10-2.53) compared with clinicians without EHR. Clinicians with access to both outpatient and inpatient EHR were significantly more likely to report high coordination for all three measures of coordination: access to timely and complete information (OR=2.69, 95% CI: 1.39-5.20), clinician agreement on treatment goals and plans (OR=2.36, 95% CI: 1.21-4.60), clinician agreement on roles and responsibilities (OR=1.96, 95% CI: 1.04-3.69) compared with clinicians without EHR.

For care transferred across delivery sites, clinicians with access to only outpatient EHR did not report significantly higher coordination than clinicians without EHR for any of the three coordination measures. However, clinicians with both outpatient and inpatient

EHR, were significantly more likely to report high coordination than clinicians without EHR for two out of three measures: access to timely and complete information (OR=1.97, 95% CI: 1.02-3.84); clinician agreement on treatment goals and plans (OR=2.02, 95% CI: 1.09-3.74).

**Figure 2: Adjusted model of clinician reported care coordination by use of EHR**



Note: GEE model, adjusted for clinician age, race/ethnicity, gender, job title, weekly hours worked, survey year, and includes medical center fixed effects. Outpatient EHR implementation occurred between 2005 and 2008, while inpatient EHR was deployed between 2007 and 2010. Reference was no-EHR access.

## Discussion

EHR has the potential to significantly improve clinical care delivery, however surprisingly little is known about the effect of EHR use on patient care coordination. We examined the impact of implementing a commercially available, integrated outpatient-inpatient EHR system on primary care providers' reports of three important elements of coordination for care transferred across clinicians and across delivery sites: (1) access to complete and timely information; (2) clinician agreement on treatment goals and plans; and (3) clinician agreement on roles and responsibilities. As expected, we found that clinicians using EHR implemented only in outpatient clinics reported significantly higher rates of coordination for care transferred across clinicians than clinicians without access to any EHR, but no significant improvements in coordination for care transferred

across delivery sites. This makes sense, as EHR can only be used as a tool for coordinating care across delivery sites when the system is integrated across outpatient and inpatient delivery sites. Similarly, we found that clinicians working in medical centers with both inpatient and outpatient EHR systems were significantly more likely to report positive coordination outcomes for all three measures of coordination when care is transferred across clinicians and to report having access to complete and timely information and agreement on the patient's treatment plan for care transferred across delivery sites. Implementation of EHR in outpatient clinics alone was not associated with any significant improvements in care coordination across delivery sites. Outpatient EHR systems should be integrated with inpatient EHR systems.

One of the principle functions of an EHR system is to provide all clinicians and medical staff involved in a patient's care with current and comprehensive patient health information at the point of care. As expected, the element of care coordination which was most highly associated with EHR use was access to complete and timely information. In addition, EHR systems allow clinicians to better document the patient's care plan and facilitate communication across multiple clinicians. Therefore we also expected that the effects of EHR use on clinician agreement on treatment goals and plans to be substantial, and our results confirmed this prediction. Conversely, specific clinician responsibilities are not explicitly documented in an EHR system, thus we expected that the effects of EHR use on clinician agreement on roles and responsibilities to be more limited. Accordingly, in the adjusted model, we did not see any significant improvements in this measure for care transferred across delivery sites; however, we did observe moderate improvements in clinician agreement on roles and responsibilities for care transferred across clinicians for those in the final phase of implementation, using the integrated outpatient-inpatient EHR.

Although the improvements in coordination associated with EHR use captured by our study are already substantial, they may be underestimating the true impact of EHR over time. In 2008, at the time of the last wave of survey collection, implementation of the inpatient EHR was not yet complete throughout the IDS. Improvements in coordination of care may continue to increase as medical centers have more time to adjust to the new system and more hospitals within the IDS complete the implementation of the EHR system.

It is important to note that this study was conducted among primary care providers from a single IDS, using a single EHR system. In other settings, the effect of the EHR system on care coordination may differ. Second, our outcome variables of care coordination were based on self-reported data, not on an audit of actual information available. These clinician-reported coordination measures provided a unique opportunity to examine effect of EHR on coordination of care, since audit trails do not provide any measures of care coordination.

The introduction of the EHR system in outpatient clinics was associated with substantial improvements in primary care providers' access to complete and timely information and in clinician agreement on treatment goals and plans for care transferred across clinicians. Implementation of the EHR system across both inpatient and outpatient clinics was associated with significant improvements in access to complete and timely



information, clinician agreement on both the patient's treatment plan and each other's roles and responsibilities. Future studies should examine whether these improvement in coordination of care result in changes in the quality of care and outcomes for patients with complex care needs. EHR systems that are integrated across delivery sites represent an important tool for facilitating the coordination of patient care across clinicians and delivery sites.

## Appendix: Care Coordination Correlation Matrix

Coordination of Care Across Delivery Sites (e.g., from the hospital to the outpatient team)

	Access to complete information	Access to timely information	Agreement on treatment goals	Agreement on roles and responsibilities
Access to complete information	1.00			
Access to timely information	0.80	1.00		
Agreement on treatment goals	0.56	0.57	1.00	
Agreement on roles and responsibilities	0.54	0.56	0.74	1.00

Coordination of Care Across Clinicians (e.g. from a specialist to the primary care team)

	Access to complete information	Access to timely information	Agreement on treatment goals	Agreement on roles and responsibilities
Access to complete information	1.00			
Access to timely information	0.77	1.00		
Agreement on treatment goals	0.48	0.47	1.00	
Agreement on roles and responsibilities	0.45	0.46	0.68	1.00

**CHAPTER 3: LINKING THE PIECES TOGETHER - THE IMPACT OF ELECTRONIC HEALTH RECORDS AND TEAMWORK ON CARE TRANSITIONS**

## **ABSTRACT**

**Objective.** To examine the impact of an integrated outpatient-inpatient EHR on care coordination across delivery sites, and whether teamwork among primary care team members modifies this effect.

**Study Design/Data Collection.** Self-administered surveys collected from all primary care clinicians working in a large integrated delivery system over three years during the staggered implementation of an EHR. Response rates were 48.1% (N=565) in 2005, 61.5% (N=678) in 2006, and 60.8% (N=626) in 2008. Using multivariate regression, we examined the combined effect of EHR and team cohesion on three clinician reported measures of care coordination across delivery sites.

**Principal Findings.** For clinicians working in teams with high cohesion, the integrated inpatient-outpatient EHR was associated with significant improvements in all care coordination measures (OR=2.53, [95%CI: 1.63-3.93] for access to timely and complete information; OR=2.43 [1.50-3.95] for agreement on treatment goals; and OR=1.74 [1.09-2.77] for agreement on responsibilities). We found no significant association between the EHR and care coordination for clinicians working in primary care teams with low cohesion.

**Conclusion.** The impact of EHR use on care coordination depends on the strength of primary care team members' working relationships. Teams with strong relationships more successfully leveraged the EHR to achieve greater improvements in care coordination.

**Key words.** Electronic Health Records, care coordination, primary care, teamwork

## Introduction

A growing number of Americans are living with chronic conditions that often require coordination between multiple sites of care, such as from the hospital to primary care [1-4]. In the current environment, where patient care is increasingly fragmented, effective care coordination is essential to ensure quality care [8, 11]. Health care innovations such as bundled payments, accountable care organizations, and incentive payments for 'meaningful use' of electronic health record (EHR) seek to improve care in part through better coordination [32, 67]. Even in an integrated delivery system implementing a complete integrated outpatient-inpatient EHR system, variations in the team working relationships could impact any potential benefits of the EHR.

Evidence suggests that care for patients with chronic diseases is best achieved when done by high functioning multidisciplinary teams in primary care [2, 5, 20]. In addition, organizational theory proposes that the team environment is critical for the successful implementation of new technologies [25, 26]. The implementation of new technology, such as EHR, undoubtedly disrupts the team's clinical workflow and routines. Primary care teams need to work together to adjust to the inevitable changes brought on by the EHR. Learning is achieved through both formal and informal channels. Still, while formal learning is critical for instilling the basics of EHR use, informal learning, which is reinforced through ongoing communication and the strength of working relationships may be critical to maximize the effectiveness of the new technology [26]. Members working in teams with strong working relationships may be more comfortable experimenting with the new technology through trial and error and sharing best-practices learned with each other. This may speed the collective learning and ensure that clinicians leverage all of the functions of the EHR in order to maximize any potential gains in care quality and prevent any possible unintended adverse consequences.

The transfer of patients across delivery sites has been shown to increase the risk of medical errors, whereas efforts to coordinate care delivery have resulted in improvements in safety [52, 98]. Poorly executed care transitions can lead to greater use of hospital, emergency, and ambulatory services [5, 52, 56, 103, 104]. The implementation of an Electronic Health Record (EHR) could be key in facilitating the transfer of information and improving coordination of patient care across care delivery sites, such as from the hospital to primary care. While EHR has been consistently promoted as a policy priority for improving the quality and efficiency of the American healthcare system, there is still limited research evidence to inform policy-makers about the effects of EHR on care coordination [18, 94], and no evidence on how organizational factors may modify this effect.

We examined the combined effect of an integrated outpatient-inpatient certified-EHR and team orientation on care coordination across delivery sites in a prepaid, integrated delivery system (IDS). We used surveys data collected from all primary care clinicians working in the IDS over three years (2005, 2006, and 2008), during the staggered implementation of a commercially available, integrated EHR system. We hypothesized that the use of the integrated EHR would result in improvements in all reported measures of care coordination and that this association would vary by level of team cohesion and would be stronger for teams with high cohesion.

## **METHODS**

### **Study Setting**

This study was conducted in Kaiser Permanente Northern California (KPNC), a large, prepaid Integrated Delivery System (IDS) providing comprehensive medical care for over three million members. Adult primary care clinicians worked in the Internal Medicine and Family Medicine departments and were grouped in 110 primary care teams, across 18 Medical Centers.

### **Health Information Technology**

In February 2005, the IDS began a five-year staggered implementation of a commercially available, integrated outpatient-inpatient certified-EHR system. The system was rolled out in two phases: staggered deployment of the system across outpatient clinics (2005-2007), and staggered deployment across inpatient hospitals (2007-2010). Medical centers typically implemented the inpatient EHR system about one year following the outpatient clinic implementation. Once implemented, use of the EHR system was mandatory.

The EHR completely replaced the paper-based medical record and a limited patchwork of pre-existing non-integrated health IT tools. Use of those early health IT tools was limited, as paper-based alternatives were still in use. The EHR is an EpicCare®-based integrated Health IT system that increased the amount of information available at the point-of-care, presenting integrated clinical information in an electronic medical record, with comprehensive computer-based provider order entry, sophisticated decision-support tools for lab testing and treatment-intensification, and secure messaging between providers and with patients. This system has been certified as a complete EHR, thereby qualifying for federal “Meaningful Use” payments.

### **Survey Collection**

In 2005, 2006, and 2008 we mailed a self-administered questionnaire to all adult primary care clinicians working in the IDS, including physicians (MD or DO), nurse practitioners, and physician’s assistants. We excluded clinicians who did not have an active panel of patients at the time of the survey. Each clinician received a letter introducing the study, a copy of the survey, and a pre-paid return envelope. Respondents who completed the survey received a small gift card. Non-respondents were re-sent reminder letters and surveys; up to four follow-up mailings were sent during each year of survey collection.

The study population included 1,175 clinicians in 2005; 1,103 clinicians in 2006; and 1,030 clinicians in 2008. Overall, 565 primary care clinicians responded in 2005 (48% response rate), 678 in 2006 (62% response rate), and 626 in 2008 (61% response rate).

## **Survey Instrument**

### Care Coordination

On the survey, we asked clinicians about four dimensions of coordination when care is transferred across delivery sites (e.g., from the hospital to the outpatient team). We asked them: “How often does each of the following occur when care is transferred across delivery sites?”

- “All relevant medical information is available.”
- “The information transfer is timely, i.e. available when it is needed.”
- “All clinicians agree on the treatment goals and plans.”
- “All clinicians agree on roles and responsibilities of each party.”

The response categories were: never, rarely, sometimes, usually, and always. Questions on care coordination were developed by an expert panel of scientific advisors specifically for this study.

### Team cohesion

Questions on team cohesion and communication included the following four items developed using published validated instruments [40].

- When there is conflict on this team, the people involved usually talk it out and resolve the problem successfully.
- Our team members have constructive work relationships
- There is often tension among people on this team (reverse scored)
- The team members operate as a real team

Response options included a 5 point Likert agreement scale (1-5).

### Covariates

In addition, the survey collected several respondent characteristics, including race/ethnicity, gender, and job title. We supplemented survey responses with information attained from the IDS’ automated database on certain PCP characteristics, including age, gender, job title, and race/ethnicity.

## **Data Analysis**

### Dependent variables

We examined three outcome measures of care coordination for care transferred across clinicians and across delivery sites. First, we combined responses to the survey questions asking if ‘all relevant medical information is available’ and if ‘information transfer is timely’. We reasoned that in order for information to be useful when coordinating care, it must be both complete and timely. In addition, responses to the two

original survey questions were highly correlated (0.8). We created a dichotomous outcome measure, 'Access to complete and timely information'. This variable was coded as one if the respondent reported 'always' or 'usually' to both questions, otherwise it was coded as zero.

For the other two coordination measures, we created two separate dichotomous variables called "agreement on treatment goals and plans" and "agreement on roles and responsibilities"; each was coded as one if to the clinician responded that the relevant agreement 'always' or 'usually' occurs, otherwise it was coded as a zero. The number of missing values was small (<5%) and not correlated with EHR status, therefore missing responses were dropped from the analyses.

### Independent variables

The main independent variable of interest is the interaction effect of use of the integrated outpatient-inpatient EHR and primary care team cohesion. We defined each primary care clinician's integrated EHR status at the date they completed the survey based on their team and hospital's EHR status. Clinicians needed to work in facilities where both the inpatient and outpatient EHR components were implemented to qualify as having an integrated EHR.

For team cohesion we calculated the average response over the four team cohesion items and aggregated them across all members from the same primary care team. The overall measure demonstrated high internal consistency reliability with a Cronbach Alpha coefficient of reliability of 0.83. We then categorized team cohesion scores into quartiles, and created a binary indicator measure for teams in the lowest quartile.

### Model

To analyze the interaction effect of using an integrated EHR system and team cohesion on our three measures of care coordination, we used a generalized linear latent and mixed models (GLLMM) logistic regression with random intercepts for clinician and medical center. We included the following clinician characteristics as covariates: age, gender, race/ethnicity, and job title. We also included a year indicator variable to control for time trends that may have affected the dependent variables but were unrelated to the implementation of EHR. Models included interaction between the indicator for low team cohesion and integrated EHR status.

The model below is a two level model with random intercepts for repeated individual clinician observations (i) and medical center level (j) cluster. In this model, I control for year and effect using dummy variables. The regression coefficient  $\beta_2$  addresses the question of whether use of an integrated, commercially available EHR system associated with clinician reported measures of care coordination when team cohesion is high (i.e., the low team cohesion indicator equals zero).  $\beta_5$  provides the estimated effect of low team cohesion on care coordination when EHR is equal to zero, meaning when clinicians are not using the integrated inpatient-outpatient EHR system.  $\beta_6$  addresses the main research question of whether team cohesion moderates the effect of EHR use



on care coordination. The remaining coefficients serve to control for the effect of any secular trends ( $\beta_3$  and  $\beta_4$ ), and clinician characteristics ( $\beta_7, \beta_8, \beta_9, \beta_{10}$ ).

**Equation 1:**

$$\begin{aligned} \text{Logit}\{\Pr(\text{Care coordination}_{ijk} = 1 | x_{ijk}, \varsigma_{jk})\} \\ = \beta_1 + \beta_2 \text{EHR}_{jk} + \beta_3 Y2006_{ijk} + \beta_4 Y2008_{ijk} + \beta_5 \text{LowTeamCohesion}_{jk} \\ + \beta_6 \text{LoTeamCohesion} * \text{EHR}_{jk} + \beta_7 \text{Female}_{ijk} + \beta_8 \text{White}_{ijk} + \beta_9 \text{Physician}_{ijk} \\ + \beta_{10} \text{Age}_{ijk} + \varsigma_{jk}^{(2)} + \varsigma_k^{(3)} + \epsilon_{ijk} \end{aligned}$$

$$\epsilon_{ij} \sim N(0, \theta)$$

$$\varsigma_j^{(2)} \sim N(0, \psi^{(2)})$$

To calculate the estimated EHR for clinicians working in team with high and low cohesion, we multiplied the interaction OR estimate by the low team cohesion and EHR estimates. We used results from our logistic regression models to compute the marginal adjusted percent of respondents who reported each outcome by fitting each model as if all respondents had (1) no EHR and low team cohesion, (2) no EHR and high team cohesion, (3) EHR and low team cohesion, and (4) EHR and high team cohesion.

As a sensitivity analysis, we ran all models excluding teams with fewer than four respondents (N=51) and attained comparable results. All analyses were implemented using Stata 10 (StataCorp LP, College Station, TX).

**Results**

Table 1 shows the characteristics of respondents who completed the survey in 2005, 2006, and 2008. In 2005, none of the respondents had access to the integrated EHR; by 2006, only 6.3% of respondents were using the EHR, and in 2008, 52% of respondents were using the integrated EHR. We compared respondents and non-respondents on several characteristics, and in 2005 and 2006, we found that female clinicians and nurse practitioners and physician assistants were more likely to respond, and in 2006 and 2008, younger clinicians were more likely to respond.

Table 1: Respondent characteristics by survey year

	2005 % (N=565)	2006 (N=678)	2008 (N=626)
Response Rate	48.1	61.5	60.8
Gender: Male	45.3	46.0	48.3
Female	54.7*	54.0*	51.7
Race/Ethnicity: Non-white	51.0	56.9	60.8
White	49.0	43.1	39.2
Job Title: N.P/P.A.	15.8*	11.7*	5.6
M.D./D.O.	84.3	88.4	94.4
Age: 25-39	36.0	38.1*	39.5*
40-54	47.5	45.1	44.8
55+	16.5	16.8	15.7
EHR Status: No EHR	100.0	93.7	52.2
Integrated EHR	0.0	6.3	47.8

Note: 262 clinicians completed the survey in all three waves of data collection (2005, 2006, and 2008), 609 completed at least 2 surveys, and 1,207 completed at least one survey.

\*p<0.05 comparing respondent and non-respondent characteristics each year, represents groups that were more likely to respond.

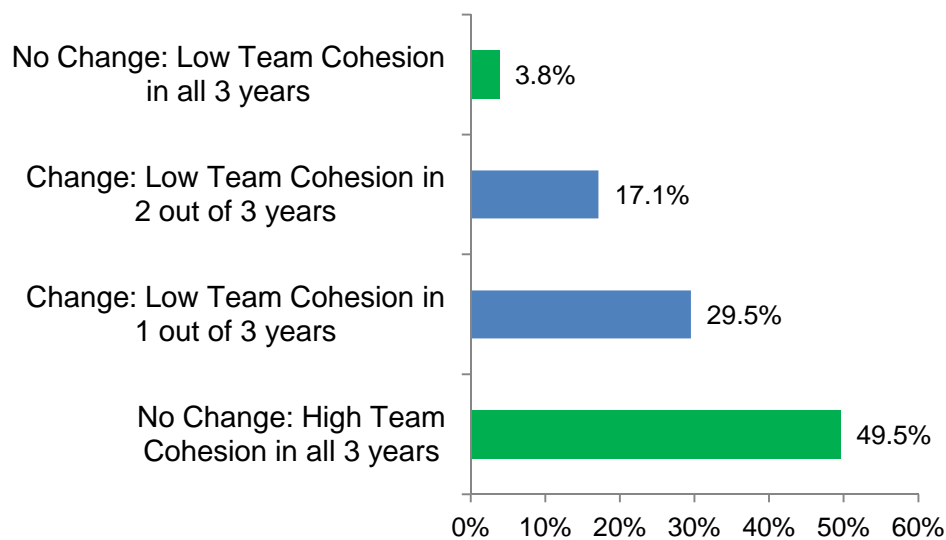
Table 2: Team Characteristics (mean, standard deviation)

	2005		2006		2008	
N =	105	106	106	104	104	104
Primary care clinicians per team	11.14	(3.78)	10.4	(3.86)	9.86	(5.92)
Respondents per team	5.39	(2.32)	6.40	(2.71)	6.01	(4.24)
Team cohesion score*: low	3.30	(0.35)	3.23	(0.35)	3.18	(0.42)
high	3.87	(0.27)	3.87	(0.23)	3.83	(0.19)

Note: I calculated team cohesion scores by averaging responses over the four team cohesion survey items and aggregating them across members from the same primary care team. We categorized team cohesion scores into quartiles and created an indicator for low cohesion for teams in the lowest quartile. Team cohesion scores ranged from 1 to 5, with 5 representing the highest level of cohesion.

Table 2 shows characteristics of the primary care teams. In 2005, teams had an average of about eleven primary care clinicians working per team, and that number decreased slightly to ten primary care clinicians per team in 2008 (range 3-25). Figure 1 shows the stability of the team cohesion indicator during the study (2005-2008). Overall, 53% of primary care teams had no changes in their team cohesion indicator during the study, and 79.0% of teams had two or more years with high team cohesion.

Figure 1: Stability of Primary Care Team Cohesion Indicator in 2005, 2006, and 2008 (N=104)



Note: Includes 104 teams with non-missing team cohesion scores across all three survey years

Table 3 displays the results from the logistic regression analyses for the three coordination measures for care transferred across delivery sites. For clinicians working in teams with high cohesion, those using the integrated outpatient-inpatient EHR were significantly more likely to report access to timely and complete information (OR=2.53, 95% CI: 1.63-3.93), clinician agreement on the patient's treatment goals and plans (OR=2.43, 95% CI: 1.50-3.95), and agreement on each other's roles and responsibilities (OR=1.74, 95%CI: 1.09-2.77) compared with clinicians without the integrated EHR. For clinicians working in teams with low cohesion, we did not find any significant association between use of the integrated EHR and reports of care coordination. The effect of the integrated EHR for teams with low cohesion was 63% and 64% lower than for teams with high cohesion for reported access to timely and complete information lower and clinician agreement on treatment goals and plans respectively ( $p < 0.05$ ). This difference was not statistically significant for agreement on roles and responsibilities. For clinicians without the integrated EHR, those working in teams with high cohesion were significantly more likely to report agreement on each other's roles and responsibilities than those working in team with low cohesion (OR=0.59, 95%CI:0.42-0.84).

Table 3. Logistic regression of clinician reported coordination measures for care transferred across delivery sites with random intercepts for clinician and medical center

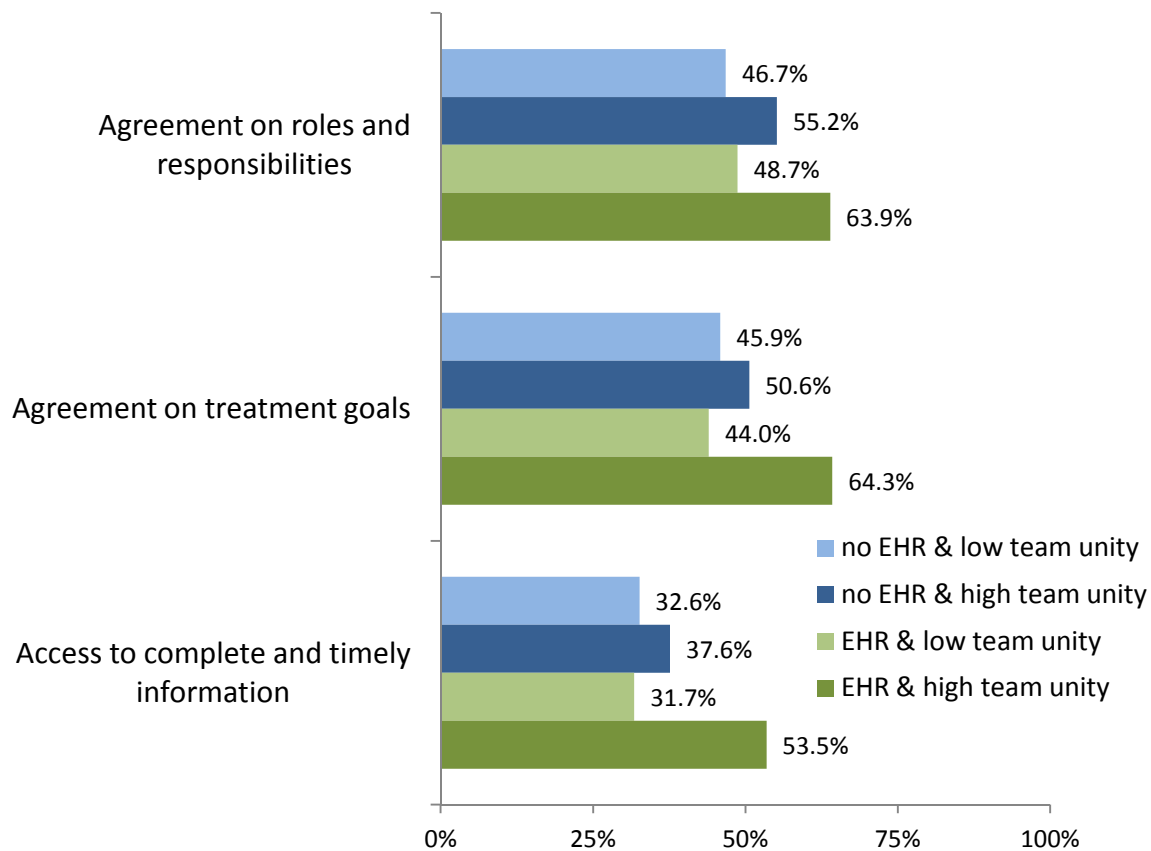
	Access to complete and timely information		Agreement on treatment goals & plans		Agreement on roles & responsibilities	
	OR	95% CI	OR	95% CI	OR	95% CI
No EHR & high team cohesion	Ref.		Ref.		Ref.	
No EHR & low team cohesion	0.73	0.52,1.03	0.74	0.52,1.06	0.59**	0.42,0.84
EHR & high team cohesion	2.53***	1.63,3.93	2.43***	1.50,3.95	1.74*	1.09,2.77
EHR & low team cohesion <sup>1</sup>	0.69	0.31,1.52	0.65	0.29,1.49	0.67	0.30,1.48
Interaction: EHR*low cohesion	0.37*	0.16,0.90	0.36*	0.14,0.92	0.65	0.27,1.58
Year: 2006 vs. 2005	0.83	0.61,1.12	0.75	0.55,1.04	0.77	0.57,1.05
2008 vs 2005	1.14	0.79,1.64	0.87	0.59,1.29	0.94	0.65,1.38
Female vs. male	0.85	0.61,1.18	0.88	0.61,1.26	1.07	0.75,1.52
White vs. non-white	0.73	0.52,1.02	0.76	0.53,1.10	0.87	0.61,1.25
MD vs. NP/PA	1.88*	1.05,3.37	1.89*	1.01,3.54	2.46**	1.35,4.48
Age: 40-54 vs. 25-39	1.13	0.81,1.58	0.69*	0.48,1.00	0.73	0.51,1.04
55+ vs. 25-39	1.73*	1.07,2.82	0.75	0.44,1.28	0.79	0.47,1.33
N	1794		1772		1763	

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

<sup>1</sup>The OR for EHR & low team cohesion was calculated by multiplying the OR for No EHR & low team cohesion, EHR & high team cohesion, and EHR\*low team cohesion interaction.

Figure 2 shows the adjusted percent of respondents who reported each care coordination outcome by EHR status and team cohesion level. After adjustments, for the three coordination measures, we observed a similar pattern, where clinicians working for teams with low cohesion reported lower levels of coordination across all measures, with almost no change before and after the EHR. The increase in reported coordination was significantly greater with EHR use for teams with high cohesion compared with teams with low cohesion. Reported access to complete and timely clinical information was substantially greater with EHR use for teams with high cohesion (54% vs. 38% pre-EHR) compared with teams with low cohesion (32% vs. 33% pre-EHR); Likewise, for reported clinician agreement on treatment goals and plans for teams with high cohesion (64.3% vs. 50.6% pre-EHR) compared with low team cohesion (44.0% vs. 45.9% pre-EHR) and agreement on roles and responsibilities for teams with high cohesion (63.9% vs. 46.7% pre-EHR) compared with clinicians working in primary care teams with low cohesion (48.7% vs. 46.7% pre-EHR).

Figure 2: Adjusted clinician reported care coordination by EHR and team cohesion



Note: We computed the marginal adjusted percent of respondents who reported each outcome by fitting the logistic regression models as if all respondents had (1) no EHR and low team cohesion, (2) no EHR and high team cohesion, (3) EHR and low team cohesion, and (4) EHR and high team cohesion.

## Discussion

EHR has the potential to significantly improve clinical care delivery, however surprisingly little is known about the effect of EHR use on patient care coordination and how the organizational work environment may modify this effect. We examined the impact of implementing a commercially available, integrated outpatient-inpatient EHR system on primary care providers' reports of three important elements of care coordination across delivery site and how team working relationships may modify this effect. We found that EHR use was associated with significantly higher levels of coordination for clinicians working in primary care teams with high cohesion, but not for those working in teams with low cohesion.

While I had expected clinicians working in teams with higher cohesion scores to experience greater benefits from the EHR on care coordination than those in primary care teams with low cohesion, I hypothesized that all clinicians report higher levels of care coordination with use of the integrated EHR. I was surprised to find that in adjusted

analyses, clinicians working in teams with weak working relationships did not experience any improvements in any of our three measures of care coordination with use of the integrated EHR.

One of the principle functions of an EHR system is to provide all clinicians and medical staff involved in a patient's care with current and comprehensive patient health information at the point of care. Therefore, at least for this coordination outcome, I expected all clinicians to benefit greatly from the integrated outpatient-inpatient EHR. The EHR clearly provides clinicians with more information than what was previously available when patient care is transferred across delivery sites.

On the survey, we gave primary care clinicians a chance to add free-text comments on the barriers to coordination. Although, there was agreement that there was certainly more information available with the EHR, the EHR was cited for creating a new problem of perhaps too much information, much of it redundant and not helpful, possibly rendering the relevant parts easier to miss. For example, one clinician stated:

*"Sometimes there is too much information from the patient's hospital stay, you can see all notes including nursing, discharge planner, etc. Health Connect should be able to limit the notes only from MD and let us expand it if we like. But right now, we see everything- and have to filter it ourselves to get only MD notes. Very time consuming and most of the time we only want to see MD notes anyway."*

Although the patient's information may be complete and available, clinicians can reported having a difficult time locating the relevant information in a timely manner. For example, another clinician reported:

*"The question is not if the information is available but if we have time to access it or can find it."*

In addition to possibly taking more time to find the relevant information, the increase in the quantity of information, much of it redundant could cause clinicians to miss critical information from the patient's medical record.

*"There is so much information and repetition in the system. It's easy to miss the important points."*

So while the EHR provided more information, for the information to be accessible, all users of the system need to know in which sections of the EHR to record the relevant information and also where to look when retrieving information from others. It is possible that clinicians working in less cohesive, more stressful primary care team environments, may have entered important clinical information in miscellaneous sections of the EHR, rather than finding the optimal location. Likewise, the extensive reporting requirements combined with limited time, may have caused clinicians to cut and paste irrelevant and possibly outdated information in the patients record.

It is clear that EHR systems are not silver bullets that will automatically result in better coordination of care and quality. In fact, unless clinicians learn to efficiently use the EHR and adapt their workflow accordingly, it's possible that it could result in greater inefficiencies and even adverse outcomes. Effective learning on how to use the system is critical to not only maximize gains in quality of care.

While formal learning is critical for instilling the basics of EHR use, informal learning, which is reinforced through ongoing communication and the strength of working relationships may be critical to maximize the benefits of the new technology [26]. All primary care clinicians in our setting received the equivalent formal classroom-style training on how to use the EHR; however, informal learning likely varied significantly across primary care teams. Members working in teams with strong working relationships may have been more comfortable experimenting with the new technology through trial and error and more willing to share learned best-practices with each other. This may speed the collective learning of this new tool and ensure that clinicians maximize the potential benefits of the EHR while avoiding unintended consequences. In fact, many clinicians reported learning more on how to use the EHR and integrated into their practice from colleagues than from the formal training provided. For example, primary care clinicians reported:

*"I learned the most from colleagues; it's helpful when we all meet to share knowledge"*

*"[I learned to use EHRs] mostly by practicing, trying to solve problems, talking to other people, and a lot of trial and error."*

The implementation of an EHR can certainly disrupts the team's clinical workflow and routines. How quickly and efficiently primary care teams can adjust to these new routines likely depends on the strength of their working relationships. Although all clinicians undoubtedly had access to more information, how quickly and efficiently they were able to access the relevant information depended on their team environment.

It is important to note that this study was conducted among primary care providers from a single IDS, using a single EHR system. In other settings, the effect of the EHR system on care coordination may differ. Still, the EHR studied is an EpicCare®-based system, which is commercially available and used by one in four physicians in the US. Second, our care coordination and team cohesion measures were based on self-reported data, not on an audit of actual information available. These clinician-reported coordination measures provided a unique opportunity to examine effect of EHR on coordination of care, since audit trails do not provide any measures of care coordination. Likewise, measures of team working relationships can only be captured through self-reported data. We had a high level of response and multiple respondents per each team. In addition, I ran models limiting data from teams with five or more respondents and the results were comparable.

There is documented variability on how successful clinical practices are at implementing EHR systems, where some have been met with worker resistance and few resulted in noted failures [27]. While EHR systems vary in their degree of usability, users also differ

in their level of computer skills. There are likely many factors that contribute to the successful implementation of an EHR system. Not all EHR systems and organizational structures will result in the same level of improvements in care quality from the EHR, and some may even result in greater inefficiencies and adverse outcomes. In our study, we found benefits of integrated EHR on care coordination depended on the strength of working relationships between primary care team members.

The introduction of an integrated outpatient-inpatient EHR was associated with significant improvements in all reported measures of coordination for care transferred across delivery sites for clinicians working in teams with high cohesion; however we did not find any association of use of the integrated EHR on coordination for clinician working in teams with low cohesion. Organizational attributes of the work environment, such as team working relationships, impact the effectiveness of this new technology. Future studies should examine how changes in care coordination measures impacts patient outcomes and examine whether these differences in the EHR effect by team working relationships persist over time.



**CHAPTER 4: THE IMPACT OF ELECTRONIC HEALTH RECORDS AND TEAMWORK ON QUALITY OF DIABETES CARE**

## ABSTRACT

**Context.** Previous studies of the association between electronic health records (EHRs) and patient's clinical outcomes have found mixed results and none have explored how the organizational context may modify the EHR-effect.

**Objective.** We examined whether cohesion among primary care team members modified the effect of EHR use on clinical outcomes for patients with diabetes.

**Design.** Previously validated survey measures of team cohesion were collected from primary care team members in 2005 (N=780, 50% response rate) before the staggered implementation (2005-08) of a commercially available, certified outpatient EHR system. Using survey and automated claims data, we examined the interaction effect between team cohesion and EHR on glycemic control and cholesterol levels in 2005-2009 for patients with diabetes. We used multivariate regression to adjust for secular time trends and patient-level fixed effects.

**Setting.** Kaiser Permanente Northern California, a large integrated delivery system.

**Patients.** 80,611 patients with diabetes mellitus.

**Main outcome measures.** Hemoglobin A1c (HbA1c) and low-density lipoprotein cholesterol (LDL-C)

**Results.** Teams varied substantially in their baseline levels of cohesion. The outpatient EHR was associated with statistically significantly greater reductions in HbA1c and LDL-C among patients cared for by teams with higher team cohesion compared with those cared for by teams with lower cohesion ( $p < 0.01$ ). Among patients cared for by teams with higher cohesion, the EHR was associated with a decrease of 2.15 mg/dL (95%CI: 1.86-2.43 mg/dL) in their LDL-C and 0.11% (95%CI: 0.09-0.12%) in their HbA1c results compared with a decrease of 1.42 mg/dL (95%CI: 1.03-1.80 mg/dL) in their LDL-C and 0.08% (95%CI: 0.07-0.10) in their HbA1c for patients cared for by teams with lower cohesion.

**Conclusions.** Team cohesion is critical to fully realize the potential care quality gains from EHR use. We found that patients cared for by clinicians working in primary care teams with lower cohesion experienced significantly reduced improvements from the EHR compared with patients cared for by teams with higher cohesion. It is important to account the organizational context, in particular team functioning, when examining the impact of EHR on care quality outcomes.

## Introduction

Widespread adoption of electronic health records (EHRs) has been consistently promoted as a policy goal that can improve the quality and efficiency of the American healthcare system. In 2011, eligible physicians began receiving billions of dollars in federal incentive payments for meaningful use of certified EHRs [22, 23, 28]. While the meaningful use criteria were carefully developed to target improvements in the overall quality of healthcare, they do not specifically address any organizational attributes of the work environment. As many studies have demonstrated, the healthcare system consists of a diverse myriad of types of providers and work environments [105].

Further, despite the focus on physician EHR use, once implemented, the system is typically used by all members of the care team, including non-physician support staff. How well teams work together to adopt this new technology may be critical to maximize its potential benefits. Teams with strong working relationships may facilitate informal learning of the EHR by encouraging open communication and sharing best practices with each other. It is likely that the effectiveness of EHR to improve patient care may depend on the organizational context in which it is used. Previous studies of the effects of health information technology (IT) on diabetes clinical outcomes have been mixed, with some showing improvements in LDL-C and HbA1c values [106], whereas others reported mixed or even negative results [107-112]. Variations in the organizational attributes of the work environment may help explain these conflicting findings.

In 2001, the Institute of Medicine called for a redesign of the health care delivery system centered around primary care teams [8]. Existing evidence suggests that team care is associated with greater work satisfaction, perceived effectiveness, patient satisfaction, and better clinical outcome measures when compared with traditional non-team care [12, 85, 86]. Communication and collaboration across team members are especially important for managing the care of chronically ill patients and to adapt to new practices and technologies [20, 82, 113-116]. Recent calls for the adoption of the medical home model emphasize the importance of teams in the provision of care [58, 117, 118]. Other literature suggests that teams can differ in how well they work together and whether they achieve their goals [20, 32, 113, 116, 119].

In prior work, we have demonstrated that widespread adoption and use of a commercially available and federally certified outpatient EHR by physicians within a large integrated delivery system resulted in improvements in diabetes monitoring and treatment, and in patient physiologic outcomes such as lipid and glycemic levels [120]. In this study, we explore the heterogeneity of these effects by examining how perceptions of primary care team function moderates the effect of EHR on clinical quality measures for patients with diabetes.

Specifically using a previously validated measure of constructive working relationships among primary care team members called team cohesion [31, 33, 35, 40], we examined whether team cohesion prior to the implementation of a certified outpatient EHR modified the effect of EHR use on lipid and glycemic levels for patients with diabetes mellitus. We hypothesized that primary care teams with high levels of cohesion would

achieve greater improvements from EHR use on these disease control measures compared with teams with a lower baseline level of team cohesion.

## **Methods**

### **Setting**

We conducted this study at Kaiser Permanente Northern California (KPNC), a large prepaid integrated delivery system (IDS) providing comprehensive medical care for more than three million members, including outpatient, inpatient, emergency department, pharmacy, and laboratory services. Between 2005 and 2008, KPNC implemented a commercially available outpatient certified-EHR. The implementation was staggered across 110 primary care teams in 17 medical centers, providing a quasi-experimental setting to examine the effects of EHR and teamwork with concurrent-controls to adjust for secular trends in diabetes care practices unrelated to the EHR. The outpatient EHR completely replaced the paper-based medical record and a limited patchwork of pre-existing non-integrated health IT tools. Use of those early health IT tools was limited, as paper-based alternatives were still in use.

The EHR adopted is a commercially available EpicCare®-based system that has been certified as a complete EHR, thereby qualifying its users for federal “Meaningful Use” payments. The system provides clinicians with complete health information at the point of care, as well as results management, order entry and management, clinical decision support, secure messaging, patient support, population management, and administrative support. Once implemented, the system was used by physicians, nurses, and other support staff.

### **Study Population**

The study population included IDS members who were in the health plan’s diabetes clinical registry as of the last quarter of 2003. We then used IDS administrative data to link patients with their primary care provider and team. We excluded members who had changes in their primary care team linkage during the study period (1/2005-12/2009). In addition, members left the study cohort when they first dis-enrolled from the IDS (average 4.9% per year) or died (2.6% per year).

### **Outcome measures- HbA1c or LDL-C Value**

Using health plan’s automated data, we collected all HbA1c and LDL-C values for the patients in our study cohort during the study period, between January 1, 2005 and December 31, 2009.

## **Team cohesion measure**

We mailed a self-administered questionnaire to all adult primary care team members, including physicians, nurses, and other support staff, working in the IDS in 2005 (N=780, 49% response rate) before the staggered implementation of the EHR. For this study, we excluded six teams with fewer than three respondents, resulting in valid team cohesion scores for 95% of the primary care teams (N=104) working in the IDS in 2005.

Between June and December in 2005, primary care team members received a letter introducing the study, a copy of the survey, and a pre-paid return envelope. Respondents who completed the survey received a small gift card. Non-respondents were re-sent reminder letters and surveys; up to three follow-up mailings were sent.

Questions on team cohesion and communication included the following four items developed using published validated instruments [31, 33, 35, 40].

1. When there is conflict on this team, the people involved usually talk it out and resolve the problem successfully
2. Our team members have constructive work relationships
3. There is often tension among people on this team (reverse scored)
4. The team members operate as a real team

Response options included a five point Likert agreement scale (1-5) and were averaged over the four team cohesion items for each respondent and aggregated across members from the same primary care team. The overall measure demonstrated high internal consistency reliability with a Cronbach Alpha coefficient of reliability of 0.83. To create a binary indicator of low team cohesion, we then categorized team cohesion scores into quartiles and created an indicator for teams in the lowest quartile.

The Kaiser Foundation Research Institute Institutional Review Board reviewed and approved the study protocol.

## **Data Analysis**

We linked all patients in the study population to teams with a valid baseline team cohesion indicator. To determine EHR status, we linked each patient in the study population to the medical facility where they sought care, and defined each patient's tests according to whether the EHR was in use at their facility at the time of the test. We defined a facility as using the EHR once it was used for at least 80% of outpatient visits in a given calendar month. For each patient, we separately classified the first test after EHR implementation as having been done during the process of transition to the EHR, since it likely captured effects of treatment decisions based on the previous test value obtained pre-EHR. We defined each patient's second and subsequent values after EHR implementation as being post-EHR follow-up values. This allowed for the patient to be fully exposed to the EHR and its potential effect on treatment and follow-up care.

Our study included the 80,611 patients in the health plan's clinical diabetes registry at the end of 2003. During the study period (2005-2009), these patients had a total of

598,924 HbA1c and 549,619 LDL-C tests; 60.1% of HbA1c and 58.4% of LDL-C tests were done after the implementation of the certified-EHR.

To examine the interaction between team cohesion and EHR use on follow-up HbA1c and LDL-C values, we used linear regression models with fixed-effects at the patient level, adjusting for calendar quarter and year. In addition, we also used logistic regression models with fixed-effects at the patient level adjusting for the same covariates to examine the interaction effect of team cohesion and EHR use on follow-up binary measures of good clinical HbA1c and LDL-C control (e.g., HbA1c $\leq$ 7% and LDL-C $\leq$ 100 mg/dL). All models included an interaction variable of the EHR status and their primary care team’s indicator for low team cohesion. To calculate the estimated EHR effect for patients cared for by clinicians working in teams with low cohesion, we multiplied the EHR effect estimate by the estimate for the interaction effect of EHR and the low team cohesion indicator.

As a sensitivity analysis, we ran all models using random-effects at the patient level while controlling for patient characteristics (including gender, age, race, chronic disease indicators) and attained comparable results to the fixed effects models. All analyses were implemented using Stata 10 (StataCorp LP, College Station, TX).

## Results

Table 1 provides a description of the primary care teams (N=104) included in the study. The average team size was 15 team members with a range of 5 to 37 members, including an average of 12 primary care providers (PCPs) per team. The average team cohesion score was 3.71 (a score of 5 represents the highest possible level of cohesion), with a range from 2.84 to 4.42 (SD=0.29). Teams with lower cohesion (i.e., in the lowest quartile) had a mean team cohesion score of 3.36 (0.14).

Table 1: Team Characteristics (N=104)

	Mean	Std. Dev.	Min	Max
Team Size	15.38	5.13	5	37
PCPs per team	11.82	4.66	1	37
Team Response Rate	0.50	0.16	0.17	1.00
Respondents per team	7.50	2.98	3	16
Team cohesion score by quartile:				
1 <sup>st</sup> (lowest)	3.36	0.14	2.84	3.52
2 <sup>nd</sup>	3.63	0.06	3.54	3.71
3 <sup>rd</sup>	3.80	0.06	3.71	3.91
4 <sup>th</sup> (highest)	4.05	0.13	3.92	4.42

PCP=primary care provider

Note: I calculated team cohesion scores by averaging responses over the four team cohesion survey items and aggregating them across members from the same primary care team. I then categorized team cohesion scores into quartiles. Team cohesion scores ranged from 1 to 5, with 5 representing the highest level of cohesion.

Table 2 describes the individual characteristics of respondent and non-respondent primary care team members working in the IDS in 2005. We were able to compare respondents and non-respondents on several characteristics, and although they were comparable on age and race, team members who were male and physicians were less likely to have completed to our survey.

Table 2: Primary care team member characteristics in 2005

	Respondents (N=780)		Non-respondents (N=824)		p-value
	%	N	%	N	
Total (N = 780)					
Age group, yr					
25-39	35.0%	273	30.9%	255	0.109
40-55	48.3%	377	46.5%	383	
55-75	16.7%	130	19.3%	159	
Missing	0.0%	0	3.3%	27	
Male gender	40.5%	316	47.0%	387	0.003
Missing	0.0%	0	2.9%	24	
Race					
Non-white	46.3%	361	47.8%	394	0.206
White	53.7%	419	49.0%	404	
Missing	0.0%	0	3.2%	26	
Job Title					
PCP (M.D./D.O.)	65.0%	507	72.9%	601	0.001
PCP (N.P/P.A.)	12.7%	99	6.4%	53	
Health Educator	2.3%	18	4.1%	34	
Pharmacist	1.9%	15	0.5%	4	
Nurse (LVN/RN)	7.2%	56	6.3%	52	
Behavioral Medicine Specialist	5.1%	40	4.7%	39	
Physical Therapist	5.8%	45	5.0%	41	
Team Tenure, yr					
0-2	22.6%	176	Not available		
3-5	31.9%	249			
6-32	36.0%	281			
Missing	9.5%	74			

Table 3 shows patient characteristics at baseline; 84% were over the age of 50, 48% were white, and many had other chronic conditions in addition to diabetes.

Table 3: Patient characteristics

Total (N = 80,611)	%	N
Age group, yr		
1-29	1.0%	815
30-49	15.2%	12,280
50-64	39.0%	31,445
65-74	25.3%	20,398
75+	19.4%	15,673
Male gender		
Missing	0.0%	23
Race		
Asian	16.3%	13,157
Black	9.8%	7,863
Hispanic	13.6%	10,924
Other	4.0%	3,214
White	48.1%	38,771
Missing	8.3%	6,682
Low Neighborhood SES		
Missing	2.6%	2,118
Other chronic conditions		
Asthma	13.0%	10,459
CAD	20.0%	16,090
Hypertension	73.9%	59,564
Heart Failure	11.0%	8,850

Note: All members with Hispanic ethnicity are categorized as having Hispanic race/ethnicity.  
SES=Socioeconomic status

Table 4 displays the results from our multivariate analysis of the combined effects of team cohesion and EHR use (i.e., an interaction) on patients' HbA1c and LDL-C values. There were statistically significant interactions between team cohesion and EHR use on improvements in patient HbA1c and LDL-C levels ( $p < 0.01$ ). Specifically, patients cared for by clinicians working in primary care teams with high cohesion had substantially better patient outcomes with the EHR compared with patients care for by teams with low cohesion. Patients cared for by clinicians working in primary care teams with high cohesion experienced a 0.11 percentage point (95%CI: 0.09-0.12%) decrease in HbA1c and a 2.15 mg/dL (95%CI: 1.86-2.43 mg/dL) reduction in LDL-C with use of the EHR compared to a 0.08 percentage point (95%CI: 0.07-0.10%) decrease in HbA1c and 1.42 mg/dL (95%CI: 1.03-1.80 mg/dL) reduction in LDL-C with the EHR for patients cared for by clinicians working in primary care teams with low cohesion.

Similarly, in the logistic models we found that the association of EHR use and good physiologic control among patients with diabetes ( $HbA1c \leq 7\%$  and  $LDL-C \leq 100$  mg/dL) was significantly higher for patients treated by primary care teams with high cohesion compared with those treated by teams with low cohesion ( $p < 0.01$ ). Specifically, the EHR effect on having an  $HbA1c \leq 7\%$  was significantly greater for patients cared by teams in



with high cohesion (OR=1.16, 95%CI: 1.12-1.20) compared with those cared for by teams with low cohesion (OR=1.05, 95%CI: 1.00-1.10). Likewise, the EHR effect on having an LDL-C≤100 mg/dL was significantly greater for patients cared by clinicians working in primary care teams with high cohesion (OR=1.21, 95%CI: 1.17-1.21) compared with those cared for by clinicians working in teams with low cohesion (OR=1.14, 95%CI: 1.08-1.20).

Table 4: Association between the interaction of team cohesion and EHR use on HbA1c and LDL-C values

Linear models of continuous test values					
	HbA1c			LDL-C	
N(labs)	598,924			549,619	
N(patients)	79,214			79,433	
Average change in:	HbA1c (%)	95% CI	LDL-C (mg/dL)	95% CI	
No EHR	Reference		Reference		
EHR & high team cohesion	-0.11***	[-0.12,-0.09]	-2.15***	[-2.43,-1.86]	
EHR & low team cohesion	-0.08***	[-0.10,-0.07]	-1.42***	[-1.80,-1.03]	
Logistic models of binary measures good clinical control					
	HbA1c < 7%		LDL-C <100 mg/dL		
N(labs)	372,970		369,014		
N(patients)	40,841		45,468		
	OR	95% CI	OR	95% CI	
No EHR	Reference		Reference		
EHR & high team cohesion	1.16***	[1.12,1.20]	1.21***	[1.17,1.26]	
EHR & low team cohesion	1.05*	[1.00,1.10]	1.14***	[1.08,1.20]	

Note: EHR effect for teams with low cohesion was calculated by multiplying the EHR effect estimate by the interaction of EHR and team cohesion. We used linear and logistic models with fixed effects at patient level, adjusted for calendar quarter, calendar year, and dummy variables to control for medical center fixed effects. EHR = Electronic Health Record, CI = Confidence Interval, LDL-C = Low Density Lipoprotein-Cholesterol, HbA1c= Glycosylated Hemoglobin A Protein.

\* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001

## Discussion

We found that the effect of EHR on clinical performance varied by baseline level of team cohesion, with more cohesive teams achieving better results than less cohesive teams. Even within a single, large IDS, we still found substantial variability in perceived levels of team cohesion across the primary care teams. Our results confirmed our previous finding that use of a commercially-available certified-EHR was associated with improved physiologic levels of HbA1c and LDL-C among all patients with diabetes [120]. More importantly, we found that those patients cared for by clinicians working in teams with high team cohesion experienced significantly greater improvements in their lipid and glycemic measures from use of the EHR compared with those cared for by teams with low cohesion. Our study demonstrates the importance of accounting for attributes of the

organizational work environment when evaluating the effect of new technologies and practices on care quality outcomes.

Since the Institute of Medicine called for a redesign of the health care delivery system centered around primary care teams over ten years ago, the use of teams in healthcare organizations has been steadily increasing [8]. Team care has been shown to be particularly important for treating patients with chronic diseases [85]. The instrument used in the current study to measure team cohesion was specifically designed to describe the quality of working relationship and communication between primary care team members. The quality of relationships is crucial for establishing the collective capacity for change, such as successfully adopting new technologies like EHRs, which inherently demand significant changes to the clinical workflow [20, 82, 113-115, 121-123]. Recent calls for implementing the medical home model and the development of Accountable Care Organizations (ACO) further emphasize the importance of team based patient care. While there are many potential models for functional ACOs, ranging from virtual physician organizations to multispecialty group practices, integrated delivery systems, such as Kaiser Permanente, arguably represent the highest level of structural integration. IDS typically involves common ownership of hospitals, physician groups, and insurance plans. It is likely that in less integrated systems, cohesiveness among primary care team members will generally be lower and more varied than those observed at KPNC.

In addition to policies that encourage the use of teams in primary care, the federal government is also making a significant investment to promote the widespread adoption and use of EHRs among physicians. Starting in 2011, physicians began receiving federal incentive payments for meaningful use of certified EHRs, which can reach up to \$63,000 per physician [95]. The definition of meaningful use was developed to incentivize the targeted use of EHR to promote improvements in the quality of healthcare. However, this definition does take into consideration any attributes of the organizational environment. In addition, while the policy focuses solely on EHR use by physicians, once the system is implemented, typically all members of the practice, including support staff, may be compelled to use it. Policies that focus solely on physician use of the technology and do not account for the organizational environment and teamwork may be shortsighted. In fact, our findings suggest that team functioning may be essential to maximize any potential benefits of EHR use on the quality of chronic disease care. Although previous studies have examined the association of team measures and care quality [105, 124, 125] as well as team care and the implementation of new technologies [126, 127], none have analyzed the interaction of team functioning and use of new technologies on clinical care quality outcomes.

There are several limitations to the generalizability of our findings. This study was conducted in a single IDS, using a single EHR system. In other settings, the team structure will differ with some physicians practicing without teams and others with much larger teams. We would expect that perceptions of team cohesion would similarly vary to a larger degree. It is possible that the effect of the EHR and its interaction with team cohesion on care outcomes may differ in other settings. Still, the EHR studied is an EpicCare®-based system, which is commercially available and used by one in four

physicians in the US. Also, while we used a rigorous quasi-experimental study design with concurrent controls, since this is an observational study we cannot rule out unmeasured confounding. Finally, although our measure of disease control (HbA1c $\leq$ 7% and LCL-C $\leq$ 100mg/dL) are widely-used population measures of diabetes quality, individualized patient treatment goals may vary.

This is the first study to demonstrate that team functioning does significantly modify the EHR effect on patient outcomes. It is possible that variations in the organizational attributes of the work environment, such as primary care team members' working relationships, may help explain some of the conflicting results found of the EHR effect on diabetes outcomes in other healthcare settings.

Understanding how the organizational context moderates any potential benefits of EHR use is particularly important given the growing emphasis on integrated, team oriented care and concurrent large investment in promoting meaningful EHR use. Although all primary care team members received equivalent formal classroom style training on use of the EHR, informal training likely varied significantly across teams. It is possible that greater team cohesion may have resulted in more effective learning about how to use the EHR through informal channels, such as greater frequency of communication with each other about the information provided in the EHR. In fact, on the survey of primary care team members, many respondents reported that learning how to use the EHR informally from colleagues was more valuable to them than the formal classroom style training they received. In addition, a cohesive team environment where members have strong working relationships may encourage learning through promoting experimentation via trial and error and sharing of best practices with each other.

For the future projects, I would like extend this work to include other health care delivery settings and conduct a follow-up study to explore the possible pathways in which team cohesion modifies the impact of EHR on care quality. It is conceivable that higher team cohesion promotes faster learning of the EHR, allowing clinicians to achieve better outcomes more quickly, but that eventually all teams achieve the same level of improvement from the EHR. Conversely, it is also possible that the EHR allow higher functioning teams to perform better as a team, magnifying the differences between lower and higher functioning teams. I also want to examine whether other organizational factors, such as culture and leadership, have a similar moderating effect on the impact of EHR on care outcomes I also want to explore how other factors, such as other characteristics of the organization and team, may change the EHR effect on patient care. It is also important to understand which factors promote greater team cohesion, including the roles played by organizational culture and leadership.

Health Information Technology, and specifically EHR, offer new opportunities for improving overall quality of care, preventing medical errors, and reducing health care costs. Still, EHR systems are not silver bullets and their impact on care quality and efficiency will be limited if any deficiencies of the work environment and team relationships are not mutually addressed. Understanding the conditions necessary to maximize any potential benefits of EHR use is a critical policy area in need of more evidence. To our knowledge, no published studies have examined the interaction of organizational attributes and the EHR effect on clinical measures of chronic disease

care.

In conclusion, team functioning is an important moderator of the effect of EHR use on physiologic measures of disease control for patients with diabetes. Patients cared for by primary care teams with low cohesion experienced significantly smaller improvements in their HbA1c and LDL-C levels from use of the EHR. The organizational context, in particular team cohesion, is critical to fully realize the potential gains in care quality from EHR use. Policies aimed at increasing targeted EHR use to improve care quality should consider including combined interventions that aim to improve team integration.

## Appendix: Goodness-of-Fit

To demonstrate the goodness-of-fit of my modeling approach, I used the model results to calculate estimated outcomes for each decile and plotted these estimates against the mean values calculated using the actual observed data. For the logistic models, I used the same approach, but calculated predicted probabilities instead of predicted values. Figures A1 and A2 show the goodness-of-fit of my modeling approach. Both the linear and logistic models with patient level fixed effects appear to adequately represent the data.

Figure A1: Model generated estimates and observed HbA1C and LDL-C values: A goodness-of-fit plot for the linear regression analysis using fixed effects

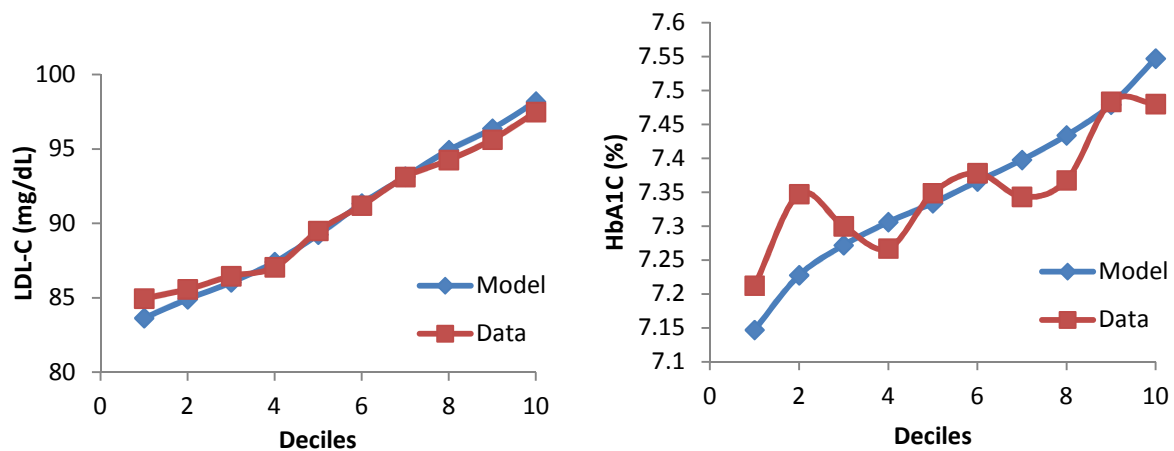
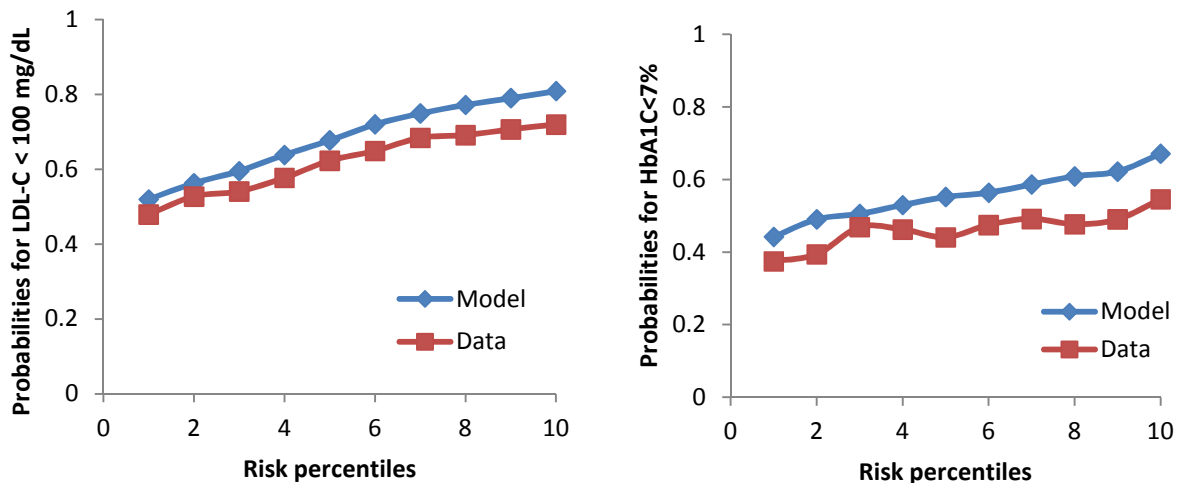


Figure A2: Model generated and observed probabilities of good HbA1c and LDL-C control: A goodness-of-fit plot for the logistic regression analysis using fixed effects



Note: To demonstrate the goodness-of-fit of my modeling approach, I used the model results to calculate estimated outcomes for each decile and plotted these estimates against the mean values calculated using the actual observed data. For the logistic models, I used the same approach, but calculated predicted probabilities.

## **CHAPTER 5: CONCLUSION**

### **Limitations**

It is important to note that this study has several limitations. Data for this study was collected from primary care providers and patients within a single IDS. In other, more fragmented settings, the effect of the EHR use and team cohesion on care coordination and patient's clinical outcomes may differ. Given the integrated organizational structure of the IDS, it is possible that reported coordination and team cohesion may be higher compared with those found in other settings. However, it is important to distinguish integrated organizational structure from care coordination. Even in integrated systems, we still observed significant variation in care coordination. Importantly, the EHR system in the study setting is commercially available and widely used in a variety of care delivery settings. Additionally, our measure of care coordination and team cohesion are based on self-reported data, not an audit of actual information available; however, such measures are unavailable.

One of the greatest concerns for any observational study is the possibility of a differential selection bias. The primary care clinician surveys had limited response rates, which could limit the generalizability of the results. Still, clinician populations are notoriously difficult to recruit, and our response rates are comparable to those of other published survey studies with similar populations. In addition, we were able to collect a wide range of relevant data, and adjust for several potential categories of confounders including demographic, clinical, and organizational variables. Although confounders are always a great concern in any non-experimental analyses of clinical data, this concern is partially attenuated given the longitudinal nature of this study. In the analyses of patients' clinical outcomes, I used fixed effects for patients, which limits the analyses to only within patient changes. Also, since the study was limited to patients that did not have any changes in the primary care linkage, this method of analyses allowed me to control for all patient, physician, and medical center time stable characteristics. The staggered nature of the EHR implementation allowed me to have a study design that included data of concurrent control groups, thus permitting separation of the background effects from the EHR effect.

### **Implications**

EHR has great potential for improving care coordination, especially for patients with the complex healthcare needs. This patient population is growing rapidly and the complexity of their care underscores the importance of timely integrated clinical information to facilitate delivery of high quality coordinated care. The staggered EHR implementation within the KP IDS created an ideal natural experiment for understanding the effects of integrated EHR on care coordination, and the combined effect of team cohesion and EHR use on coordination and quality outcomes. No studies have used longitudinal data to examine how the impact of use of commercially available, certified EHR systems on care outcomes is modified by primary care team members' working relationships. This

study is the first to demonstrate that the association of EHR use on care coordination and quality vary by team working relationships.

I first examined how use of an outpatient EHR and an integrated inpatient-outpatient EHR was associated with coordination of care across clinicians and across delivery sites. I found that while the introduction of an outpatient EHR was associated with substantial improvements in coordination of care across clinicians; it was not associated with improvements in coordination across delivery sites. Reassuringly, I found that the implementation of the integrated outpatient-inpatient EHR system was associated with significant improvements in coordination of care across delivery sites and across clinicians. EHR systems that are integrated across delivery sites represent an important tool for facilitating the coordination of patient care across clinicians and delivery sites; however, use of stand-alone EHR systems may not result in improvements in care coordination.

While my first analyses focused on the population averaged effect of the EHR use on coordination outcomes, in my second paper, I examine how the specific effects of use of the integrated outpatient-inpatient EHR on coordination of care across delivery sites vary by primary care team member working relationships and cohesiveness. Surprisingly, I found that while use of the integrated EHR was associated with significant improvements in all reported measures of coordination for clinicians working in teams with high cohesion, I did not find any benefits of EHR use on coordination for clinicians working in primary care teams with low cohesion scores. Future studies should examine how changes in care coordination measures impacts patient outcomes and examine whether the difference in the EHR effect by team cohesion persist over time.

I then analyzed how the effect of use of an outpatient EHR on clinical outcomes for patients with diabetes vary by primary care team member's working relationships and cohesiveness. I found that while EHR use resulted in improved physiologic measures of disease control for all patients with diabetes, team functioning is an important moderator of this effect. Patients cared for by primary care teams with low team cohesion experienced significantly smaller improvements in their HbA1c and LDL-C levels as a result of the EHR. Conversely, teams with strong working relationships more successfully leveraged the EHR to achieve greater improvements in care quality.

This study leveraged survey data obtained in previous studies and multiple linkable datasets. The 2009 stimulus bill allocated billions of dollars to promote the adoption and meaningful use of EHR. In fact, the definition of meaningful use was specifically designed to target care coordination and care quality. Still, there is limited research on the effect of EHR on care coordination and how the team environment can modify the impact of the EHR on care outcomes. This study provides important evidence on the role of EHR use on care coordination and quality improvement that are broadly applicable across the nation. In the current clinical environment, where care provided to patients is increasingly fragmented, and also increasingly complex, effective care coordination is essential. Health Information Technology, and specifically EHR, offer new opportunities for improving overall quality of care, preventing medical errors, and reducing health care costs. Still, EHR systems are not silver bullets and their impact will

be limited if any deficiencies of the work environment and team relationships are not mutually addressed.

Organizational attributes of the work environment, such as team working relationships, significantly impact the effectiveness of the EHR on coordination and patient quality outcomes. The organizational context, in particular team cohesiveness, is critical to maximize any potential gains in care quality from EHR use. Policies aimed at increasing targeted EHR use to improve care quality should consider including combined interventions that also address team integration. Future studies should continue to explore how other factors, such as other characteristics of the organization and team, may modify the EHR effect on care quality. It is also important to understand which factors promote greater team cohesiveness, including the roles played by organizational culture and leadership.



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