THE ELECTRONIC HEALTH RECORD: EFFECTS ON CLINICIAN COLLABORATION IN PRIMARY CARE

By

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A DISSERTATION with Multiple Manuscripts

Presented to the Department of Medical Informatics and Clinical Epidemiology

and the Oregon Health & Science University

School of Medicine

In partial fulfillment of the requirements for the degree of

Doctor of Philosophy

March, 2015

School of Medicine

Oregon Health & Science University

CERTIFICATE OF APPROVAL

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A multi-manuscript dissertation

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Acknowledgements

Writing a multi-manuscript dissertation is a funny process. While my name is the only one on the author block for this dissertation, in reality there have been many authors and contributors. Even though I am responsible for the preparation of this document, and am/will be primary author on the three articles, there are many people I need to acknowledge.

My committee and co-authors

David Dorr, MD, MS has been my mentor and advisor, and has borne the brunt of many hours of reviewing and providing constructive feedback, counseling, and often provided insights that cut the Gordian knots.

Joan Ash, PhD, MBA, MLIS is not only the reason I came to OHSU, but has been a constant positive presence, a thoughtful reviewer, and a valuable reference as I did this work. She is an incredible role model and I can't thank her enough.

Deborah Cohen, PhD has been the reviewer/co-author willing to stand up and tell me when we were off base, a valuable expert on both how medical practices really work, and someone who epitomizes the best in academic research. Her comments have been consistently insightful and have made this research much better.

Gary Olson, PhD is a true expert on collaboration and technology. He has been the outside viewpoint in this process – and I've learned that his quiet questions are as valuable a teaching technique as pages of criticisms from others.

Annette Totten, PhD was a late addition to the committee, but was willing to help even before she was formally part of the process, has provided valuable comments and insights into the dissertation process, and shown a willingness to ensure the success and validity of this work.

Others

This dissertation started with a paper written in Bill Hersh's 610 class. Paul Gorman, MD was generous with his time and introduced me to the work of Clancey and Salas. Jennifer Hall, MPH helped keep me on track with the coding and analysis of the qualitative work, the SAFER team (particularly Joan Ash, Adam Wright and Dean Sittig) participated with me on the qualitative site visits, and the TOPMED team (David Dorr was PI) facilitated the survey process for the third manuscript.

Over 180 professionals and researchers participated in this work. I would particularly like to thank my colleagues at Old Town Clinic, the clinicians and leadership at the OHSU GIM clinic, and the School of Medicine Research in Progress group.

I am indebted to the Department of Medical Informatics and Clinical Epidemiology (particularly Karen Eden, Andrea Ilg, Diane Doctor, and Lynne Schwabe, and my fellow fellows for their support) and to my colleagues and students at the OHSU School of Nursing for their patience as I finished this document.

The National Library of Medicine, the Office of the National Coordinator for HIT, and the Gordon and Betty Moore Foundation provided funding for this dissertation.

ABSTRACT

Background: Electronic health records (EHRs) and collaborative healthcare delivery are two innovations implemented to meet the triple aim: improved patient satisfaction, better population outcomes, and more efficient service delivery. Both represent significant changes in how healthcare is provided. With any significant innovation there will be unanticipated results, both positive and negative. With two significant innovations, we should expect unintended consequences from the interaction of the EHR with Patient Centered Medical Homes. The EHR, then, has the potential to be a facilitator or a barrier for increased collaboration. Thus far, the literature on this topic is scant.

Objectives: In this dissertation we had three aims: 1) provide qualitative data to increase our understanding of the interaction between these two changes, 2) develop a tool to measure collaborative behaviors, and 3) analyze the association between the EHR as a communication channel and changes in collaboration behaviors between clinicians.

Methods: Aim 1 used qualitative methods, the development of the scale (aim 2) used a mixed methods approach, and aim 3 relied on principal component analysis and multi-level regression techniques.

Settings: Fourteen health care systems and clinics that had already implemented EHRs and were in the process of implementing patient centered medical homes. These settings were purposively selected to include a diversity of organizational models, geographic locations, sizes, and EHR vendors.

Results: Aim 1: The EHR played several different roles in collaboration – repository, messenger, orchestrator, and monitor, with mixed success. As a repository, the EHR can help build common ground, but can also destroy trust when documentation quality is poor. As a messenger it is easy to use, at the risk of creating an illusion of communication. In the orchestrator role, the EHR has not yet fulfilled its promise in supporting coordination of care. Finally, in the monitor role it can help bring people together, but adaptation requires that people meet and talk rather than just send notes through the EHR.

Aim 2: We were able to develop and validate a brief tool to measure frequency of collaboration behaviors (trust/respect, communication, coordination, and adaptation). We found that while these behaviors are linked, they are not prerequisites for one another.

Aim 3: Principal components analysis divided the communication channels into EHR-based channels, primarily voice-based channels, and other written channels. We found that use of the EHR for communication did not increase trust, but did increase reported levels of communication frequency and coordination for collaborations outside the clinic only. Use of the EHR for communication also did not increase the frequency of reported adaptive behaviors. Increased use of voice-based channels of communication did increase reported frequency of adaptive behaviors.

Discussion: Results from our qualitative and quantitative studies (Aim 1 and Aim 3) are very similar. Both studies found the EHR can both build and damage trust; it can facilitate communication (but not necessarily quality communication); it can help with coordination across distance, and it is not rich enough to facilitate adaptation. Because these studies were done in different settings and provider samples, this triangulation suggests the potential generalizability of study results. This research is only the start; are many confounders that need

to be further explored. Future work includes examining the relationship between increased frequency of collaboration behaviors and triple aim results and finding ways changes in EHR design and implementation can increase collaboration.

Conclusion: We have demonstrated, using different methodologies and in different clinics, that the EHR has the potential to affect how providers collaborate. We also provide a brief, unbiased, flexible tool to measure collaboration behaviors. Organizational leaders, technology designers, and implementation teams can use this tool to measure how their innovations affect collaborations. By doing so, they can better anticipate and monitor adverse effects and maximize the positive benefits of their work.

Chapter 1: Introduction

As we work to improve the effectiveness of healthcare delivery systems, improved use of technology and better collaboration are two key elements of that change.(1) This dissertation discusses the importance of these elements, shows that we can measure them, and gives an example of methodologies to monitor and shape the way we use these measures to promote learning and improvement in health care delivery.

This dissertation examines the interactions between the use of electronic health records (EHRs) and more collaborative work patterns, and provides a way to conceptualize and measure how EHRs change the way providers work together. This dissertation had three specific aims:

Aim 1: Identify the EHR's effects on provider collaboration. In this qualitative formative study, we visited five different sites across the United States and identified the roles the EHR plays in the process of professional collaboration through semi-structured interviews and observation.

Aim 2: Develop a tool to measure collaboration behaviors. We were unable to find a validated tool flexible enough to measure the broad range of professional healthcare collaborations; we needed a tool that spanned professional and system boundaries. To fill this gap we used a mixed methods approach to develop and validate a new, novel tool to measure professional collaboration.

Aim 3: Test the effects of increased EHR usage, as a communication channel, on collaboration. Using the tool we developed, we tested this tool at eight primary care clinics in Oregon. The results of this study showed associations between EHR usage and increased

communication and coordination across distance, but was not positively associated with adaptive behaviors (behaviors that requiring changing the content of tasks).

The dissertation has eight chapters. After this introduction, we discuss some of the background for the dissertation and the methodologies we use (chapters 2-3). Next are three manuscripts we have prepared (chapters 4-7), one for each of the aims. One of these manuscripts has been published in the 2014 AMIA symposium proceedings, and two are being prepared for submission to peer-reviewed journals. Finally, we discuss the implications of our work and summarize our conclusions in the last two chapters (chapters 8-9).

Chapter 2 - Background

Both the electronic health record and collaborative care models are decades old.(2,3) In the past few years, however, the implementation for both has accelerated rapidly in the United States.(4,5). Healthcare usage patterns, available resources and technology changes have combined to force multiple changes in healthcare delivery systems. It is not clear, however, whether the different changes being made to delivery will be synergistic – the total effect will be greater than the sum of the parts – or competitive – the total effect will be less than the sum.

Drivers for change

High costs/poor outcomes, an aging population with more chronic disease, and a shortage of providers are some of the forces driving change in U.S. healthcare systems. In response, the federal government is providing increased (or at least not decreased) payments to providers that adopt the EHRs and implement more collaborative healthcare delivery systems.(5) These drivers of change are significant and they are not going away.

The first driver is our high costs and poor outcomes. In 2013 the U.S. spent an average of $9,255 per person (17.3% of GDP)(6), almost three times the average cost ($3,322) for the other industrialized nations (OECD) and almost twice the percentage of GDP (OECD average 9.3%).(7) Despite this expenditure, the life expectancy at birth in the US is 78, almost two years less than the OECD average of 80.(7) And we are doing worse on nine of the ten measures tracked by the Commonwealth Fund. (8) In part, this is due to our high incidence of lifestyle-related chronic disease.

As the U.S. population ages, the need for healthcare services and the costs to provide them will also increase.(9) Per-capita healthcare costs for those over 65 in 2010 were $17, 503; per-capita costs for the 45-64 age cohort were $8,370. With the percentage of the population over 65 expected to grow by 50% (from 13% to 20%) between 2010 and 2030 (10)costs are expected to increase accordingly. Part of this cost increase will be due to more chronic disease. About half of all adults in the U.S. have at least one chronic disease; 25% have two or more.(9) Eighty-four percent of all US healthcare costs were related to chronic diseases(6). Lifestyle behavior change is key to reducing chronic disease, but this requires skills beyond the traditional medical diagnosis and treatment model.(11,12)

Not only do high healthcare costs put U.S. companies at a competitive disadvantage, but there simply are not enough providers to care for the population – especially in primary care. Demand for full time equivalent providers is projected to increase by 29,000 providers between 2010 and 2020. Even if the increased number of nurse practitioners and physician assistant providers is taken into account, the projected supply of primary care providers is 6,000 providers short of the expected supply – assuming these "mid-levels" are effectively integrated into the system.(13) This does not take into account either the increased expectations placed on primary care providers(14) or the increased provider documentation time with electronic health records (EHRs).

EHRs and collaboration as responses to these drivers

EHR adoption and increased collaboration between providers are intended to address these issues by reducing waste, providing more effective care for those with chronic diseases, and by allowing the substitution of other healthcare professionals for physicians and "mid-levels."

Reducing waste. According to the Institute of Medicine, the U.S. wastes $765 billion per year of our total spending on healthcare - approximately one-third of the total expenditures.(15) This waste is due to a number of factors, including duplicate diagnostics and unnecessary procedures, medical error, excessive administrative costs, failing to follow established guidelines and providing care in inappropriate settings (e.g. the Emergency Department rather than a primary care clinic). By sharing EHR data – through a shared system, through an Health Information Exchange (HIE), or even through electronically shared summaries - providers can view the diagnostics already performed. Improved collaboration has the potential for reducing medical error through better communication and joint decision-making, and both improved collaboration and the EHR have the potential for increasing guideline compliance.

More effective care for chronic disease. Much of chronic disease is related to "lifestyle issues." Improved diet and exercise can reduce obesity, diabetes, hypertension, and stroke risk. (9) Managing depression can result in improved medication adherence. (16) Helping patients make these changes requires skills beyond diagnosis and prescribing; monitoring, counseling, and coaching skills are also important.(3) Pharmacists, nurses, behavioral counselors, therapists, nutritionists, and others can provide effective care at lower costs than requiring physicians to provide all care, and often have skills that differ from those taught in medical school. In addition, as the amount of medical knowledge increases, specialists are needed. Specialists are usually in different clinics, and often work for different healthcare systems. Effective patient care in the 21st century will require increased collaboration between specialties and professions. It will be the role of the patient-centered medical home to coordinate them.(17)

Patient-centered medical homes are a relatively new delivery approach designed to provide access to coordinated, comprehensive, and personalized care.(17) Currently, private insurers,

Medicare and state programs are conducting trials with ambulatory clinics that have taken on this responsibility; clinics are provided additional compensation on a per-member or incentive basis to function as patient-centered medical homes, (12,18) with clinics finding a team composition and approach that enables the provision of more cost-effective care. These aren't the only changes they are making; as part of this process clinics are required to have a functioning electronic health record (EHR). The EHR is not only supposed to support twenty four hour care and teamwork, but is also the source of much of the data for performance measurement and incentive payments.

Neither collaborative care nor the EHR are new ideas.(2,3) What is new is their increasing prevalence. In the United States, the percentage of physicians with advanced capability EHRs almost doubled (to 48%) from 2009 to 2013. Further, 90% of all physicians intend to adopt an EHR in the near future.(19) In the same time period, more than ten percent of U.S. primary care practices have been recognized by the NCQA as PCMHs.(4) And the results from these initial PCMH implementations are promising. (20)

Literature review

In 2010 there were no published studies on the interaction of the EHR with collaboration behaviors. To date, there are only two qualitative studies that have explicitly examined the results of EHR implementation on collaboration, and Weir, Embi, and Hammond (21,22) have conducted both. They conducted a multi-site multi-profession review of the effects of computerized documentation in the Veteran's Administration, and found that poor quality documentation, largely caused by the use of the cut and paste function, were reducing trust. In another study with a related focus, Lanham (23) studied the effects of the EHR on communications in a large system in Texas, and found that there were distinct differences

between clinics in how they used the EHR for communications. In addition there is one quantitative study, but with an unvalidated instrument and very few results.(24) This study is discussed in chapter 8. We expect that as more collaborative healthcare delivery systems evolve, there will be more publications in this area.

Additionally, there have been findings of "unintended consequences" in studies of EHR implementations.(25,26) These studies have found disruptions in communication and workflow patterns, missed communications, and reduced collaboration between professions.

Coordination, collaboration, and teamwork

While the terms coordination, collaboration, and teamwork are frequently used in the literature, there does not appear to be agreement on what they mean. MacDonald, in her literature review performed for the AHRQ found 42 different definitions for coordination.(27) We repeated her search in 2012, and substituted the term "collaboration" for "coordination." We found 17 different definitions for collaboration in the healthcare literature. Common features of these definitions included communication, trust, shared goals, and shared decisions. Definitions also varied, and these differences seemed to be connected to the role of the primary author. When the primary author was a nurse, shared decision–making became important.(28) When the primary authors was a physician, collaboration meant working as a team to support the provider. (29) And for other professions, e.g. social workers and pharmacists, collaboration was defined as merely being part included in the process. (30)

Teamwork is a common goal for most primary care practices. According to Salas, teamwork requires leadership, mutual performance modeling, back up behavior, adaptability, and team orientation.(31) While these behaviors may be possible within a clinic, they are very difficult to accomplish when the collaborators are in variable teams, are separated by distance and/or

profession, and have different goals. Edmondson describes “virtual teaming” as a process for establishing ad-hoc teams to address these issues.(32) But often in healthcare, collaborations do not meet her criteria for teaming: although participants may share in the desire to improve the patient’s health, they may measure it differently, resulting in different goals. They may not share equally in the financial rewards from providing the care. And they may participate in a large number of “teamings” and find their time available for the behaviors needed to support the teaming practices are limited.

For the purposes of this dissertation, collaboration will be defined in terms of a set of behaviors (trust/respect, communication, coordination, and adaptation). We define trust and respect as a willingness to be vulnerable and to consider the other’s opinion, communication (defined at its most basic level) as the exchange of the minimum set of information needed by both parties to perform effectively, coordination as changing the timing of tasks to more effectively provide patient care and adaptation as tailoring the content of tasks to achieve better outcomes

Gaps in the literature

Although there are a large number of surveys that measure collaboration and coordination in healthcare, none are flexible enough to measure the wide range of collaboration behaviors found in practices (see chapter 4). And while there are a few qualitative studies and incidental reports of the interactions between EHR implementation and collaboration behaviors there are no published quantitative studies on this topic using validated surveys.

The articles from this dissertation will begin to fill these gaps.

Chapter 3 - Methods

This dissertation topic is novel. At the time we started work on the dissertation (2010), we were unable to find any peer-reviewed qualitative work dealing with the interaction of the EHR and collaboration behaviors. Nor was there a validated instrument to measure the collaboration behaviors across all of the combinations of professions and systems (arguably still true). And there still is very little quantitative data on the extent – or even existence – of these interactions. As a result this dissertation required a broad range of research methods. To examine the roles of the EHR in collaborations we used qualitative methods – this provided a foundation for our research and helped illuminate the questions. When we couldn't find a tool that was flexible enough to measure healthcare behaviors, we built it using mixed methods. And finally, in order to test our hypotheses, we used quantitative methods.

Settings

We were particularly interested in collaboration for primary care providers; the implementation of both the patient-centered medical home (PCMH) and the EHR results in a "natural experiment" in which to study the EHR's effects on collaboration. These changes, however, are also increasing the demands on providers – making it more difficult to enlist them in research studies. We were very fortunate in that we were able to incorporate our work into two larger research studies. By doing so, we were able to enlist the help of over 180 professionals who participated as interview subjects, allowed us to observe them, and/or completed surveys for us.

Data collection for Aim 1 was conducted as part of the SAFER (Safety Assurance Factors for EHR resilience) study.(33) The SAFER project resulted in guidelines for the safe implementation and use of EHRs and related systems. These sites were purposively selected to provide a cross

section of successful EHR implementations in medium to large healthcare delivery organizations. All of these sites were in the process of implementing or optimizing their patient-centered medical homes. As such they enabled a broad view of the potential advantages and challenges for collaboration in state of the art systems using an EHR. Aim 2 was conducted within the Oregon Health & Science University School of Medicine's DMICE (Department of Medical Informatics and Clinical Epidemiology) and GIM (Geriatrics and Internal Medicine) departments, as well as a federally qualified health center/patient centered medical home in Portland, Oregon. Data collection for Aim 3 was collected as part of the TOPMED (Transforming Outcomes for Patients through the Medical home Evaluation and reDesign) trial. The TOPMED trial is a pragmatic cluster-randomized controlled trial that compared different incentives, practice facilitation approaches, and IT support and their effect on the triple aim outcomes of health, cost, and patient experience.

The sampling process and data collection are described separately for our three aims in chapters four through six. Singly, any one of these data sets would provide data that might not be generalizable. However, since we obtained similar results from fourteen different healthcare organizations that were using five different EHR vendors, and implementing different versions of the PCMH we believe there is a strong likelihood that our conclusions are generalizable across a wide variety of U.S. primary care clinics.

Methods - Aim 1: Understanding the Interaction

For this aim we used qualitative methods. . Qualitative methods can serve multiple purposes, including increasing our understanding of a given situation, providing insights that allow theory

generation, confirming predictions made by a set of theories, and evaluating effectiveness of tools or practices. In this instance we used a modified grounded theory approach.

A grounded theory approach is conducted in a naturalistic setting and focuses on "a process, including human interactions, and how they result from and influence one another."(34) In this case it allows us to use interviews and observations to build a theory. One of my challenges in doing so was that I already had beliefs around collaboration patterns in primary care. To safeguard against my biases coloring the data, I worked with one of the SAFER principal investigators to identify my biases. Additionally, actual data collection and analysis was conducted with other team members who had a different set of biases. This team approach is consistent with RAP methods (35,36) and allows for triangulation of the results obtained by individuals with different backgrounds and using different methodologies. We also did data checking with key informants as part of our exit interviews at each site.

Another challenge was saturation. In qualitative research saturation refers to sampling to the point of redundancy. By doing so, we can increase the likelihood that the full range of experiences is reflected in our work. Our visits were conducted in what, for qualitative work, is a relatively short, fixed time frame (four to ten days). The participating organizations graciously allowed us access to many knowledgeable participants, but the extent of this access was limited. We did not reach saturation within any one organization, but rather demonstrated the commonality of our findings through a series of interviews and observations conducted across many organizations and sites.

Guarding against theory bias was a major challenge in data analysis process. I had already conducted my literature review and was concerned that the theories I had read – and that resonated with me based on my own clinical practice experience. This had the potential to result

in results that did not truly reflect the underlying phenomena. As described in chapter four, this series of interviews and observations were transcribed. A professional qualitative analysis and I then independently coded the transcripts. After each site visit was coded, we met to compare our results and agree on both our selection of data points and a common coding schema or codebook. After this open coding, (37) we had a period of crystallization (38) during which we had two "sense-making" sessions with the senior members of the team. In these sessions, it became apparent that axial coding – making connections between categories (37) around both EHR roles and collaboration could add some insights. Moreover, the group concluded that our many themes coalesced around the four collaboration behaviors. Based on this, we introduced some of the collaboration behavior theories as a lens from which to view and code some of the behaviors.

Methods: Aim 2 – Developing and validating a scale to measure healthcare behaviors

Tool development

From our formative qualitative work, it appeared that an amalgam of the behaviors identified by Salas, Clancey, and Kinnaman (39-42) could provide a framework for examining collaboration behaviors between healthcare clinicians. As shown in table 3.1 below, there was relatively good consistency across these theories:

Table 3.1: Behaviors identified by theorist:

	Salas	Clancey	Kinnamon
Trust and Respect	x		x
Communication	x	x	x
Coordination		x	x
Adaptive Collaboration	x	x	x

We reviewed a number of existing instruments, notably the Collaboration Wizard (an instrument developed primarily for measuring collaboration between distant "co-laboratories") and those listed in the AHRQ Atlas of Care Coordination Measures(27,43). Based on our earlier qualitative work, the work of the three theorists discussed above, and our literature review we developed a draft instrument and tested it through cognitive interviewing, first within our department and later in an internal medicine clinic. The results of this testing process are reported in Chapter 5 of this dissertation.

The process itself consisted of three rounds of user testing, with obvious flaws corrected during each round, and the instrument reviewed (twice by different expert panels) at the end of rounds two and three. Each round consisted of cognitive interviewing with seven clinicians with varied backgrounds – medical doctors, nurse practitioners, nurses, and social workers were among the professions who participated in the process. By using this iterative cognitive interviewing process, we were able to improve the usability of the instrument as well as ensuring that the survey would be consistently and correctly interpreted.

In this development process, there were four significant decisions that affected the design, reliability, and potential usefulness of the survey. First, this was self-reported data; we would

expect every participant to have their own individual biases. To some extent we were able to adjust for this by getting multiple collaboration ratings from each participant. Secondly, participants reported on their last significant collaborations – these might or might not be typical for their overall practice. There were two reasons for doing so: 1) by getting this information for enough participants we can determine the range (rather than just the "typical") of collaboration behaviors within a clinic, and 2) our test subjects told us that it was very difficult to identify a typical collaboration and much easier to identify the most recent. Next, we asked participants for data on both his/her behaviors and the collaborator's. The risk here is that participants will rate her/his own behaviors more favorably than their counterparts. We took this risk because medical collaborations are often asymmetric due to differences in professional status; one collaborator may have a greater frequency of collaboration behaviors than their counterpart with higher social status.(13) Finally, we reverse-scored three of the items. Doing so provides a check against "yes-saying" bias, but does so at while requiring increased cognitive loads – increasing the chance of an error in the response.(44) In all four of these decisions we tried to achieve higher validity, but at the cost of higher variability in the expected results.

This data, obtained as a Juster (adjectival form of Likert) scale, was scored from 1 (never) to 9 always, with the option for each participant to indicate "I don't know." Before our analyses, we tested the data to ensure it had a normal distribution. If it did, we treated the data as interval in our analysis. When it did not we treated it as categorical. Missing data was excluded on a pairwise basis.

Expert Panel Reviews

The two expert panel reviews were conducted separately by two different panels and with different objectives. The first panel reviewed the questionnaire and some preliminary testing results to establish the face validation and potential utility of the tool; the second to determine if the items were appropriate for and adequately covered the domains (content validity). The first panel was conducted as a focus group; (38) it included 18 physicians and researchers, the second was composed of four experts in collaboration and was conducted as a modified Delphi process. (45) For the focus group we presented our questionnaire and results from the preliminary data, described our objectives, and asked them to comment on the validity and usefulness of the measure. For the second (modified Dephi review) the experts were asked a series of questions and provided written responses; then they met as a group and reviewed/modified their responses based on input from the others. The first stage was consistent with standard Delphi practice, but the consensus building stages were shortened to eliminate the time lags required for subsequent individual written responses. As a result of this process, we modified the questionnaire by adding four questions. These questions were subsequently tested for consistency with the existing questions. Summaries of the first focus group comments and the second expert panel questions are attached as appendices to this chapter, as well as the final questionnaire.

Convergent, Construct and Reliability Testing

Both online and paper versions of the questionnaire were then tested in a clinical setting. This testing was intended to test for convergent and construct validity, as well as evaluate the reliability of the instrument. Each participant completed the questionnaire twice – once online and once using a paper format. Each questionnaire asked for data on two different

collaborations, one within the clinic and one outside the clinic. Gathering four different observations for each participant – 48 behavior frequencies – allowed us to make allowances for individual biases through multi-level estimation/regression and robust variance allowances.

A model for collaboration behaviors

We also used structured equation modeling (SEM)(46) as one method of testing the construct validity of the model.

In our SEM verification the equations simultaneously estimated for maximum probability were:

$$Trust = \mu_{trust} + \delta_{dist} + e_{trust}$$

$$Comm = \beta_{trust} * Trust + \mu_{comm} + \delta_{dist} + e_{comm}$$

$$Coord = \beta_{comm} * Comm + \mu_{coord} + \delta_{dist} + e_{coord}$$

$$Adapt = \beta_{coord} * Coord + \mu_{adapt} + \delta_{dist} + + e_{adapt}$$

Where μ_{trust}, μ_{comm}, μ_{coord}, and μ_{adapt} are the intercept terms, the β's are the slopes for the linear regression, δ_{dist} is the effect of being collocated, and the e terms are the residual errors.

The software used a Maximum Likelihood Estimation (MLE) to estimate the parameters (constants, independent variable coefficients, and residual error) for multiple equations simultaneously.(47,48) It starts with an initial estimate of the parameters based on a heuristic. It then calculates likelihood probability - the probability of observing the actual data values if these parameter estimates are correct. Next it calculates changes the estimate for one parameter slightly and recalculates the likelihood. If the likelihood increases, it continues to revise the parameter estimate in the same direction. If the likelihood decreases, it reverses the direction of the change. This continues until the likelihood of one parameter has been maximized, and the software then tries to determine the maximum likelihood estimate for the

next parameter. Once all the parameters have been estimated, the software has completed an iteration. The software then re-estimates the parameters, this time using the maximum likelihood estimates from the previous iteration as the starting values. This continues until the maximum likelihood no longer increases between iterations.

By doing this on a combined basis, we could test to see if the model was consistent as a whole (root mean square error of approximation or RMSEA) and how well the model fit the data (goodness of fit or GOF statistic). (46) Chapter 5 contains further information about how we applied this method and the results.

Reliability

As discussed in chapter 5, we also checked the tool for scale homogeneity, split-half reliability, and limited test-retest reliability. We instructed a group of the participants to complete their questionnaire twice on the same collaborations, but to do so from two days to two weeks apart to avoid recall effect.(44) This didn't happen as we expected. Not only did some of the participants self-identify differently as to their roles from one time to the next (for example a nurse psychologist identified herself first as a behaviorist, and then later as a nurse), but many of them also appeared to identify different collaborators - they forgot who they chose the first time. For the test-retest calculations we only used the cases where they identified the same collaborators; the small sample size resulted in higher variances and thus probably overstates the variability of the tool results.

Methods: Aim 3 – examining the association between EHR usage and collaboration behaviors

The survey instrument tested in Aim 2 also asked questions about how frequently the participants used the EHR (specifically copies of chart notes and flags and messages) and other channels. The full instrument is attached as appendix A to this chapter. The original list of channels for this instrument was based on our qualitative work (Aim 1); we added to this list and changed the wording for clarity after our cognitive interviewing and expert review processes (Aim2).

Our goal was to examine how the use of these channels was associated with changes in the frequency of collaboration behaviors. But we only had 74 providers participating in the survey (our target was 80 providers). At this level of participation and with a .05 total alpha (probability of rejecting a correct null hypothesis), we had an 80% chance of detecting an effect size of one step (out of a total of nine possible steps) with three factors, with nine factors it was only 0.25.(49) As a result, we used principal components analysis (PCA) to consolidate the number of channels into three groups. PCA analysis is a means of determining which combinations of input factors best explain the sample variability; in this case we used an oblique rotation technique to maximize the interpretability of the PCA results.(50) The PCA results are shown in chapter 6.

Once we had the factors, we then performed a multi-level regression analysis to examine the effects. We used a three level analysis – factors within individual participants within clinics.

For this multi-level estimation of the factor effects the estimate was based on:

Obs (for each factor) = $\mu_{ind +} \mu_{clinic} + \Sigma\beta_i * x_i + e$

Where μ_{ind} and μ_{clinic} are the individual biases and the clinic effect, β_i ais the amount of nd x_i are the estimated effect and frequency of channel i.

Without expecting to get statistically significant results, we also reran the analysis using all nine channels. The surprising results are also shown in chapter 6.

Triangulation

Finally, we were able to compare the results from our original qualitative study with those derived quantitatively. Concordance between these results strengthens the probability that the results are valid, and the agreement between different sites supports the generalizability of our work.

Chapter 4 – The roles of the EHR in collaboration between clinicians

(published as Chase DA, Ash JS, Cohen DJ, Hall JD, Olson GM, Dorr DA. The EHR's roles in collaboration between providers: A qualitative study. AMIA 2014 Symposium Proceedings 2014 November 14-19:1275

Abstract

Objective: Examine how the Electronic Health Record (EHR) and its related systems support or inhibit provider collaboration.

Background: Health care systems in the US are simultaneously implementing EHRs and transitioning to more collaborative delivery systems; this study examines the interaction between these two changes.

Methods: This qualitative study of five US EHR implementations included 49 interviews as well as over 60 hours of provider observation. We examined the performance of the EHR in building relationships, communicating, coordinating, and collaborative decision-making.

Results: The EHR plays four roles: a repository, a messenger, an orchestrator, and a monitor. While EHR performance varied from system to system, common themes relating to collaboration were decreased trust due to poor quality documentation, incomplete communication, potential for increased effectiveness through better coordination, and the emerging role of the EHR in identifying performance gaps.

Conclusion: Further organizational and technical innovations are needed to fulfill the EHR's roles in collaboration.

Introduction

For over a decade, experts have agreed that more collaborative, team-based care will be required to meet the increasing burden of chronic disease(3). Unlike the acute care issues that

dominated medical practice in the twentieth century, treating chronic disease on an outpatient basis will require multiple visits to providers in different disciplines. Not only will increasingly specialized medical expertise be required, but chronic disease treatment increasingly involves changing lifestyles and navigating a complex web of treatments. Different health care professionals with different skills in different locations will need to collaborate to provide a cohesive care team. This increased collaboration is likely to constitute a disruptive change in the delivery of healthcare services. Another disruptive but potentially positive change is the introduction of the electronic health record (EHR) and its related systems – computerized provider order entry (CPOE), clinical decision support (CDS) and health information exchanges (HIE).

The deployment of EHRs has resulted in many examples of "unintended consequences," outcomes that are different from those anticipated when the systems were first designed (25,51). The EHR was originally designed as an electronic implementation the paper chart (52);

Figure 4.1: The collaborative behaviors and their benefits

Collaborative Behaviors	Benefits
Trust and respect	Less need to repeat diagnostics and procedures, more willingness to hand off or delegate
Communication	Increased awareness and understanding, less mistakes due to missed data or context
Coordination	More effective processes and increased efficiency in workflows
Adaptive Collaboration	Increased understanding across disciplines, when needed provides ability to tailor plans to meet patient circumstances

supporting collaboration (other than care transitions) was not one of the original aims. These unintended consequences are not necessarily negative – one example is the ability of the EHR to support care coordination (53).

The definition of collaboration, however, appears to vary significantly. In our review of the literature the definitions appeared to depend on the role of the author: for physicians collaboration meant better teamwork (29), for nurses it meant having a role in decision-making (28), and for pharmacists it was simply to be involved in the process (30). For this study we adopted a role neutral taxonomy of collaboration behaviors based on the works of William Clancey and Eduardo Salas (31,40). These groups of behaviors are trust and respect, communications, coordination, and adaptive collaboration (see figure 4.1 above).

Team-based models based on collaboration have been implemented in primary care, the ICU, and surgical units, with improved results.(20) One prominent move towards collaboration is through the implementation of the Patient Centered Medical Home (PCMH). The configuration of the PCMH varies from system to system, (4,18) but it consistently includes increased teamwork and collaboration within the clinic, and improved collaboration with providers outside the clinic, but within the "Medical Neighborhood."

Our goal is to identify the how the different roles the EHR plays within the primary care settings of five different healthcare units affects the collaboration between providers. We do this by examining the results of our interviews, field observations, and data analysis with the lens of

these four types of collaborative behaviors suggested by the work of Clancey, Salas and Kinnamon.(31,40,41)

Methods

Purpose: This qualitative study examines how the EHR and related systems affect the collaboration behaviors between providers in five systems that are implementing Patient Centered Medical Home delivery models.

Methodology: We used a modified Rapid Assessment Process (35,54) for data collection, and a grounded theory approach (37) for analysis. At the end of each site visit we summarized our initial themes and reviewed them with the site sponsor to verify our interpretations.

Data sampling and collection: Data were collected through site visits (semi-structured interviews and field observations) at five leading-edge multi-site organizations with EHR installations in the United States. Providers at all five sites told us that they were in the process of implementing their PCMH. It was part of the SAFER project (Safety Assurance Factors for EHR Resilience). The SAFER project resulted in guidelines for the safe implementation and use of EHRs and related systems.(33) These sites were purposively selected to provide a cross section of successful EHR implementations in medium to large healthcare delivery organizations. As such they enabled a broad view of the potential advantages and challenges for collaboration in state of the art systems using an EHR. The characteristics of the sites are summarized in table 1. The visits occurred between May and November of 2012.

Within each site we identified key individuals who were involved in the implementation, use, and monitoring of the EHR. We then worked with our sponsor at the site to schedule interviews with these individuals and field observations of providers working with patients using the EHR

and other technology tools. The data used for this collaboration study consisted of 49 interviews and 60 hours of field observation; over five hundred pages of

Table 4.1: Sites visited

	Location (US)	Structure	Number of physicians/providers	EHR
Site 1	Southeast	Augmented family practice/for profit	50 to 100	Centricity
Site 2	Mid Atlantic	Integrated System/ not for profit	More than 1000	EPIC
Site 3	Midwest	Community Health Center	Less than 50	Centricity through service provider
Site 4	Midwest	Community Health Center	50 to 100	Centricity through service provider
Site 5	Northeast	Academic Integrated Health System	More than 1000	Propriety/ "Best of Breed"

transcripts and notes were annotated. The primary author and another analyst independently selected the interviews and observations included in this study; the two reviewers then met and agreed on the codebook and categories used and ultimately developed higher level patterns and themes.

IRB approvals: The Institutional Review Boards at Oregon Health & Science University and each of the sites approved the study.

Team: Each visit was conducted by a multi-disciplinary team. At a minimum, each site visit included a combination of professional qualitative researchers, informaticists and clinicians;

several visits also included an expert researcher in communications and a human factors expert. The team met daily to debrief and prepare for the next day's encounters.

Collection Methods: The team conducted refresher training in interviewing and observation techniques prior to the site visits. Semi-structured interview guides were developed for each interviewee role and organization. Questions regarding communication and collaboration were developed by the primary author and included in the interviews. All interviews were tape recorded and subsequently transcribed with the consent of the interviewees.

For the field observation, teams of two to six trained observers went to each site. We used a template for field observations that covered broad categories of foci of interest; each observer was responsible for gathering information on topics outlined on the template. The observers, however, tailored the actual field notes based on the setting. At the site, they each followed different providers. Each day they documented their observations and then discussed them with the other researchers at a daily debriefing.

At the conclusion of each site visit, we prepared a summary of findings for the entire SAFER visit and met with our site sponsors and other leaders from each organization to confirm the veracity of our data.

Data Analysis:

Coding: two of the authors independently coded data for each site visit using NVivo 10.(55) Data included interview transcripts, field observation notes, and written artifacts collected in the site visits. After each site visit was coded, the analysts met to agree on codebook categories (nodes) and relevant data elements. Both analysts for the analysis of the next site visit's data

then used this codebook. New nodes were added and old data elements reclassified after the analysis of each visit.

Theme generation: Following the initial coding, two of the authors met several times to identify common themes and implications from the analysis. This period of immersion and crystallization(38) included multiple drafts of memos and tentative hypotheses.

Practice lens: Other co-authors with subject matter expertise in informatics, communications, and clinical delivery systems reviewed the themes. In these sessions, it became apparent that the collaboration models of Clancey and Salas (31,40,41) would be a valuable organizing theme for the themes. This took place in two separate "sense-making" sessions. Our results present the products of those sessions.

Results

The data analysis resulted in 49 initial nodes related to collaboration, and these categories were subsequently combined into 17 themes. These themes, in turn, were related to four roles played by the EHR and its related systems: repository, messenger, orchestrator, and monitor.

Repository: The EHR stores and makes information accessible to providers. This includes encounter and phone notes, lab and imaging results, and information from encounters with providers outside the system. Scanning was the typical means of data input from outside the provider's own system, although we did find evidence of increasing EHR to EHR communications (e.g.CareEverywhere) and Heath Information Exchange (HIE) mediated communications.

Table 4.2: In our data, we found the EHR played four distinct roles

Role	**Performance criterion**
Repository	Contain all of the quality, accessible data needed for use by healthcare providers
Messenger	Enable information transfer and communication between providers also between providers and other members of the healthcare team
Orchestrator	Ensure that the right person is doing the right thing at the right time for the patient
Monitor	Identify care gaps for patients and populations; provide a benchmark for measuring the performance of providers and teams

Messenger: The EHR and related clinical systems have significantly expanded the number of communication channels available to providers. Now, in addition to in-person, analog written, and phone/voicemail communications, providers can transmit information and communicate with other providers using secure email, clinical messages using a paging system, messages within the EHR (which can be attached to patient records), and pop-ups and general "broadcast notices." While these messaging services can be free standing, they are often included in the EHR. In our visits, we were consistently told that sending a copy of the encounter note was the most frequent means of communication, but there were also variations in practice between providers and healthcare settings.

Orchestrator: Increasingly, health care systems are using the EHR to guide "who does what when." The design and flow of the input templates, the use of standardized order sets, the use of bundles and "smart orders" to implement best practice algorithms are increasingly used in

efforts to improve the timing, the consistency and the quality of services. “Tickler” notes were also frequently used to remind providers to perform a task. Additionally, every system we visited was concerned about having the right person for every task; this often meant having the system delegate a task – usually to have that someone work at “the top of their license.” That said, unlike the repository and messenger roles, there were significant variations in the sophistication of the EHR as orchestrator. At one site, there would be a template or form that each team member would have to open and fill in the data as they complete a task, while another might send alerts based on complex algorithms to one person or team that a task needs to be completed, and then automatically populate the template when the task was completed.

Monitor: These systems of care were all striving to improve quality. With an EHR in place, data can be collected and analyzed to reveal “care gaps.” Several of the systems we visited were using these data to evaluate the performance of teams and individual providers; these data were also used to determine incentives and guide compensation decisions. By providing “dashboard” performance summaries to teams, and individual results to providers, systems were able to give feedback that could, in turn, facilitate performance improvement. It was in this role that we found the widest variation in system capabilities. None of the sites were completely satisfied with their EHR and the associated data warehouses that they were building to facilitate analysis. Given that, however, the capabilities ranged from automating data collection for mandatory reporting (e.g. HEDIS and meaningful use data) to enabling teams to use custom data extracts as they tried to improve their performance on quality metrics.

Collaboration Behaviors and the EHR

In our interviews and observations we found that the EHR can have significant, sometimes conflicting effects on the four collaboration behaviors (trust and respect, communication, coordination, and adaptive collaboration).

Each of the four roles had a primary effect on a single collaboration behavior (figure 2 below). But they often had broader effects. In the following paragraphs we will summarize the effects of each of the roles on the four collaboration behaviors. In our interviews and observations we found significant, and sometimes conflicting effects. One aspect of the EHR can and did affect several different behaviors at once (e.g. a lack of trust due to poor data quality cascaded throughout all four behaviors), but we have tried to avoid repetition where obvious.

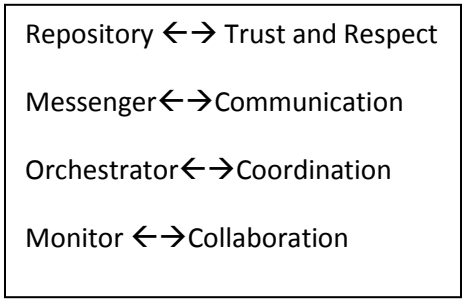


Figure 4.2: there is a one to one correspondence between the roles of the EHR and the collaboration behavior on which it has a primary effect

Repository

As a repository, the EHR had mixed effects on trust and respect. On one hand, the EHR can provide proof that one discipline could trust another: “And our physicians saw [the data from the EHR] and realized ‘wow, that really works… I can reliably delegate to my nurses.” At other times poor data quality would reduce their trust in other providers: “This note that’s 15 pages

and it looks like they spent two weeks with the patient when the reality is they spent five minutes … and everything in there is either a fabrication and or was correct two years ago but not today."

Other issues involved the lack of context and the length of notes with structured data. Time pressures are a contributing factor: "there is a trade-off between patient safety… and efficiency." "If you are a busy PCP (primary care provider) with …one minute to prepare… you don't do it as thoroughly." It is not clear, however, how much this decrease in perceived note quality is simply an artifact of increased note visibility: "people who wrote good notes on paper would write good notes in the electronic world, and people who wrote lousy notes …would write lousy electronic [notes]."

As a repository, however, the function is to store data and to make it available to others. When a provider could not find a specialist's note, she became frustrated and began to blame the other for poor communications. We later found the note, but finding the note involved paging through three screens of poorly indexed lists of chart notes, consultant's reports, and laboratory data (from our field notes)

The repository role also has an effect on the other collaboration behaviors. For communication it provided a common dataset that could speed and simplify communications; this was true, however, only when both parties had access to the same EHR. Commonly, we found that a copy of a chart note would be sent within a referral or other inter-provider communication; this provided the basis for other communications, but this often this transfer was not enough by itself, more contextual data was needed. The common data set also facilitated collaboration in multidisciplinary team meetings: "As she describes the case the psychiatrist is displaying parts of the patient's history and progress notes from the EHR on the screen."

The repository function can improve coordination as well by increasing awareness: “you can see a list of items that you need to complete for the patient. The nurse can see it, the physician can see it.” This increased awareness is, however, a two edged sword – “now we are unearthing scope of practice issues … that we didn’t have to deal with before.” Scope of practice issues varied. They might range from a pharmacist having to complete a medication order with default parameters when they couldn’t reach a provider, to a nurse pulling a physician’s “personal order set” out from under a pile. These variations from standards were much more visible when awareness increased.

Messenger

In its role of messenger the EHR and related systems affected all of the collaboration behaviors, but its primary effect was on communication. One of the key benefits is asynchronicity. This allows EHR-related communications to bridge time and space; to work with providers who are on different shifts or in different offices or clinics. It increases awareness: we know he’s checking the vitals, he’ll come when he needs to.” And it is efficient: I just write a brief note and click.” There are, however, downsides to the default asynchronicity of communication. Across all of the sites we heard: ”we call it brain freeze where with the technology implementation, they think that they can no longer talk to one another.” We also heard about the “communication illusion,” when providers thought they were communicating, but weren’t. This can result from a lack of contextual data, or from a delivery failure – particularly for lab results (“I’ve seem systems where 30% of the lab results weren’t delivered to the right person”) – was a problem that all of the sites we visited were trying to correct: “You need to have that person communicate with the primary doctor …. and then have [the primary] them assume that

responsibility and acknowledge it." The ability to bridge time also came with a draw back – the lack of simultaneity made it difficult to give feedback and clarify, which could take more, rather than less time.

Orchestrator

The primary effect of the orchestrator role was on coordination behaviors. Leadership at all of the sites was trying to use the EHR to improve quality by encouraging or 'orchestrating' "the right person doing the right thing at the right time." The use of templates, smart order sets, and bundles has the potential to increase trust and respect, facilitate information transfer, and significantly improve coordination.

These smart order sets/bundles existed at these sites only for the one to two dozen most prevalent conditions. "We have lots of initiatives … most of them boil down to sophisticated checklists." "We are already getting the … plan [before discharge]. We already know home health needs to be set up. All these things can be done ahead of time and that makes the doc's life easier." At one site they used "automation to manage the preventative care needs of 220,000 patients … delegation of tasks [to non-physicians] as well as protocol." As one of our key informants there told us, this does not happen well right after EHR implementation: "We figure it takes about three months for the dust to settle…and [then we say]: What can we improve about the process? About the EHR? …The most valuable thing that happened … was that throughout the organization there are people who, when we say process redesign, say 'Okay, when and where?'"

With smart order sets and bundles, there can be automatic dissemination and notification of results and follow-up. “We look at [who]… can perform the task. The alerts fires to them and only that person. … We make it actionable so … they can address the alert at that time. … The nurse can see it. The physician can see it. And then, further in the work flow …, if they did not address the alert, it will display again.” The ability to generate tickler (reminder) notes based on a pre-agreed plan of care is a powerful communication tool within the orchestrator role.

Unfortunately, even the best thought out and planned bundles won’t work if the providers don’t accept the process. “If we ever got any of ours 50 percent accepted, I don’t know what we’d do. We would be so excited.” One of the challenges for implementing EHR mediated coordinated care is getting physicians to trust in others: “our physicians have been trained that really the buck stops with you. … [,to offset this] we pilot everything…and then we show them it works. Time is also an issue. All of the providers we met with felt time and productivity pressures, making them resistant to additional tasks: “One the statements that can lead to failure is ‘let’s make the doctor do it …. Regardless of topic, I’ll give you about a 30% chance … [of getting it to work].” “you can have a great tool for asthma, but if it takes ten minutes to do it’s not gonna happen.”

For many of the providers delegation helped relieve the time pressure. Care plans have long been a means of facilitating collaboration and team work. Traditionally the care plan was the final element in every encounter (SOAP) note. A more subtle point is the orchestrator role requires consolidating fragmented care plans, about which one participant noted: “A human being should only have one care plan. This is a legitimate IT role.”

The EHR can only do so much to support collaboration, however; at every site we were told that when the situation was complex, they needed to meet with or “pick up the phone and call”

another provider. One clinical leader told us that, as far as collaboration was concerned, “the computer is giant hinder[ance]” When collaboration was important, so was the person to person contact – either a warm handoff, a face to face meeting, or a phone call.

Monitor:

As a monitor, the EHR makes it possible to do ongoing reviews of process and outcomes. Perhaps because this is the least developed role, we found the most variation in effects. Uniformly organizations found that setting appropriate goals was difficult: “If the A1c target is 6.9 and we are at 7.0, I’m not sure that is a fail.” And getting good data could be difficult “Our chlamydia and gonorrhea screening rates were three percent, and we said ‘no way’…. It was a problem with the coding.” But once the goals were accepted, they could be used as an impetus for change: ”We roll out the measures….[showed] there is a disconnect there… and so that allow us to change the workflow.”

When the monitoring through EHR data showed improvement, this willingness to change was reinforced. The use of dashboards, graphical indicators of provider and team performance, provided a sense of progress. The EHR as monitor could also trigger action: “every month we pull a report [of diabetics] that includes nine different measures…and we then we use this report to trigger telephone outreach…, vaccinations, …and screenings.” Sometimes, however, the goals between providers would differ, and this would lead to conflict – for example when the endocrinologists were treating to an LDL of 100, and the primary care providers were only targeting a decrease to 120 ng/dl.

Table 4.3, below, summarizes the principal effects discussed above. In each role, we found evidence that the EHR affects all of the collaboration behaviors – both supporting and inhibiting collaboration. The inhibiting actions, however, appear to be more in known behaviors, while the supporting factors are future promises:

	Repository	Messenger	Orchestrator	Monitor
Trust and respect: Enhancing positive relationships between providers	Increased awareness, but cut and paste and other quality issues decrease trust.	Asynchrony helps, but lack of richness in channel can result in misinterpretation	Particularly strong in establishing clear expectations	Key appears to be common goals and measurement
Communication: Providing the information and mutual understanding needed to care for patients	"It's all there" (potentially), but "it's hard to find"	Multiple channels can speed message delivery, but issues with "closing the loop"	Some successes, but clinical information is often not accessed/ignored by provider	When implemented can communicate gaps where practice improvement needed
Coordination: Having the right person do the right thing at the right time	A record of what actions and plans were, but each document frozen in time.	Issues due to variations in communications practice between providers	Bundles and "smart" worksheets particularly effective, but not implemented for enough conditions	Can facilitate team-based actions; if one member slips, another can fill in for them.
Collaboration: Facilitating collaborative decisions	Lack of interaction, one document per provider	No real time discussions, everything is lagged	Creates new boundaries, but doesn't encourage adaptation	Using dashboard and incentives to focus on common goals promotes dialogue

Figure 4.3: The key issues for each collaboration behavior varied by role

Limitations

In this study we focused on successful EHR implementations, organizations with less successful implementations would, presumably, have a different experience. A significant percentage of those we interviewed and our key informants are considered thought leaders within medical informatics; this may bias our results. Our conclusions were also influenced by our focus on collaboration behaviors. There are other valid viewpoints (e.g. safety, cost, patient engagement) that are not directly reflected here.

Discussion

We found four roles for the EHR – repository, messenger, orchestrator, and monitor; and that these four supported or inhibited collaboration behaviors and processes differently. The leadership groups at every clinic we visited were actively working to improve the performance of their electronic health record in each of its roles. -

Although they used different practice lenses to focus their work, other researchers have found similar issues at other locations using a different EHR. Lanham, Leykum, and McDaniel (23)used a complex systems lens to examine the effects of communication patterns on practice relationships. These relationships included trust and respect as well the appropriate use of communication channels. In a sample of six family medicine and specialty practices within a single system using the same EHR, they found that increased heterogeneity in communication patterns within each practice appeared to be related to increased practice fragmentation. Weir, Hammond, Embi et al (21) used a lens based on Clark's theory of communication, joint action and common ground to examine the effects of computerized documentation on coordination

and collaboration. Data were collected from focus groups at four different VA sites. Like our study, they found that the EHR could create a shared awareness and common database from which to act. They also found that "cut and paste" and failure to close the communications loop could create unintended consequences.(21,56) Their work also discusses the value of narrative in building and maintaining shared mental models. This data was expanded to five sites and re-analyzed by Embi, Weir, Ehthiminiadis et al (22) using a grounded theory approach. Emergent themes included the inadequacy of the EHR as a sole communication channel, difficulties in finding relevant information, and a need for better support for coordinated care, and disruptions in both trust and workflow due to problems with the EHR.

EHR related barriers to collaboration should not be a surprise. The EHR was originally intended to replace the paper chart as a repository of data that would support medical reasoning and communication.(57) But as healthcare is changing, so are the demands placed on the EHR and its related systems. To meet these new demands both technological and organizational changes are needed.

The organization changes may seem simple, but are potentially very profound. If providers are evaluated on the clarity and comprehensiveness of their notes, rather than on the number of billing factors, the quality of the notes might improve. Providers can be trained on when to use what communication channels. If all patient records had a "curator" who annotated and indexed of the documents for future use, accessibility would improve. And if providers believe their viewpoints are represented in designing new workflows, they are more likely to follow new pathways and bundles.

Technology can help as well. Better interface and data input technologies can provide time for better communications. Curation can be improved by using plagiarism tools to identify

inappropriate cut and paste. Bundles that allow for more effective pathways and delegation can also free up time for providers. Monitoring tools can identify potential open communication loops. But, more interestingly, the paradigm can be revised to fit a coordinated and collaborative process, rather than an individual practitioner. Models from other fields offer one possibility. Ratings ("Amazon") for quality and usefulness might increase the quality of notes. Better identification of team members and their capabilities ("Facebook") could increase visibility and trust.

With the advent of care managers, several "add on systems" have been developed to create a common care plan. But what is needed is a reconfiguration of the basic structure of the EHR. The ideal EHR for chronic disease management would allow for the integration of multiple care plans from different providers. This integrated care plan could be implemented as a wiki with the primary care provider or designee as the curator, or it could incorporate "column" care planning. But it would be one care plan for one person.

Conclusion

The sites we visited demonstrated the potential for the EHR to support increased collaboration as well as several barriers presented by the implementations of the current systems. By examining the performance of the EHR with a collaboration practice lens, we can identify needed improvements to support the move to more collaborative healthcare delivery. These improvements will likely be a combination of organizational and technological changes. Unless these improvements are made, the EHR will undermine trust and respect between providers, confuse communication channels and lose vital information, miss out on significant potential efficiencies due to improved coordination, and fail to support the complex decision making

needed for refractory chronic disease. The now widespread implementation of the EHR is a significant achievement.

Chapter 5: Measuring healthcare collaboration behaviors

(To be submitted to *Medical Care* on acceptance of this dissertation)

Abstract

Background: Interprofessional collaboration is emerging as a critical element of care delivery, particularly team-based care for more complex patients. There are no validated measurement tools of interprofessional collaboration flexible enough to reflect the wide variety of types of professionals and types of collaborations in which clinicians engage.

Objective: Develop and validate a tool measuring collaboration behaviors between professionals, including those in different professions, teams, clinics and systems.

Study Design: Development and validation followed a four-step process: (1) tool development based on previous qualitative work and existing theory, (2) cognitive interviewing, (3) expert panel review, and (4) validation and reliability testing.

Methods: Usability and face validity were established through two rounds of cognitive interviewing. An expert panel established content validity. Construct validity was demonstrated through statistical analysis of completed surveys (e.g., correlations, Cronbach's alpha, and structural equation modeling (SEM)). We examined the effects of distance on the measurement of collaboration behaviors to demonstrate convergent validity. Reliability testing included both split-half and test-retest measurements.

Results: The final tool took less than five minutes to complete and met validity and reliability criteria. All items were positively correlated and within-factor items were consistent (alpha from .7 to .8), but the scale as a whole was not homogenous (alpha of .31). An expanded version of the scale had more scale homogeneity (alpha of .85), but less homogeneity within factors. The

SEM model had good fit (RMSEA = .045). The tool measured the effects of distance ($p < .001$) and had good split-half reliability (Spearman-Brown prophesy .91).

Discussion and conclusion: This is a valid tool for measuring the frequency of collaboration behaviors and evaluating collaboration-related interventions in ambulatory care settings.

INTRODUCTION

There are a large number of instruments to measure collaboration, coordination, and related constructs within healthcare.(1,2) Almost all of these tools were developed to either measure and improve teamwork within one clinic or measure collaboration between two specific professions, e.g. physicians and pharmacists. But healthcare systems provide care through a fragmented network. For instance, primary care providers may collaborate with clinicians in different specialties/professions and distant clinics, often working for different healthcare systems. We have been unable to find a validated measure flexible enough to handle the wide variety of collaborations occurring in healthcare today. This article describes the development of a brief, flexible tool to provide a snapshot of the very diverse set of collaborations between clinicians in an ambulatory care environment.

The need for professionals to work together to deliver care, particularly for complex patients, creates a need for physicians to collaborate effectively with the other professionals that are involved in their patients' care. (1,17,58) Challenges related to interprofessional collaboration are critical to health outcomes; Lack of communication and collaboration has been cited as a root causes in the majority of all sentinel (adverse) events in the United States. (3) At the same time the percentage of patients seen by specialists and non-physicians is increasing, and physicians frequently don't even know the names of their collaborators. (1,17,58)

Technology and more collaborative delivery systems are intended to help; but how much do they help or hurt?

Unfortunately, few validated measures of interprofessional collaboration exist. In a review of available instruments to measure teamwork (collaboration) in healthcare, Valentine et al (59) found that there were only two validated surveys with applicability to collaboration between clinicians who are not co-located. One of these surveys was valid only for the relations between physicians and nurses; the other – Gittell's Relational Coordination (RC) measure (60-62) –has been successfully implemented across different units (e.g. admissions, surgery, radiology) within an organization, but not across different healthcare systems or corporations. What is needed is a tool, a set of questions that could be used, within a survey instrument, to measure collaboration across organizations and professions, not just functions or units within a system.

We developed a tool to meet this need. The tool that we developed was brief, and focused on the behaviors that form collaboration, making it usable for a wide range of providers in a variety of healthcare situations. We describe how we developed this tool, and report results of our reliability and validity testing.

METHODS

Tool development

The tool was developed in four stages: (1) development of survey items, (2) cognitive interviewing, (3) expert review, and (4) validation. This four-step process is a standard and

rigorous process for tool development and testing to assess validity and reliability. We describe each step in more detail below.

Initial development: Our goal was to develop a survey tool that focused on behaviors, was free of professional bias, and was brief enough to be used in conjunction with other tools. We developed our initial draft of the tool based on our earlier qualitative work (9), and, to a large degree, theories proposed by Clancey (8-9), Salas (10), and Kinnamon (11).

Clancey and Kinnamon both proposed a behavior-based taxonomy for collaboration.(10,11) We felt that evaluating actions rather than attitudes or beliefs would be likely to provide less biased responses from participants. This is in contrast to other measures that focus on either participant attitudes towards collaboration (12) or on the antecedents needed for effective collaboration (13). We wanted to measure the frequency of given collaboration behaviors without an inherent bias in favor of more complex behaviors. The scale had four different collaboration behaviors – trust and respect, communication, coordination, and what we call adaptive collaboration or adaptation. Trust and respect is a willingness to rely on another's work and accept the vulnerability that entails. (14) For communication we used the most basic definition – providing/receiving the information needed to accomplish tasks. Coordination involved changing the timing of a task, while adaptive collaboration meant adapting the content of a task.(10,11) The draft tool had respondents identify two significant patient care collaborations (those with both risk and impact); one with a co-located collaborator inside the clinic, the second a distant collaborator outside the clinic. They were asked to select roles for themselves and others from a list of five choices: "PCP, "Specialist," "Behaviorist", "Care Manager", and "other."

The draft tool then asked about the perceived frequency of one of the four collaboration behaviors for both the participant and their collaborators (eight questions) using a nine point Juster scale from never to always. The Juster scale responses were coded as 1= never, 3=seldom, 5=sometimes, 7=usually, and 9=always. Participants did this for two collaborations, one within the clinic and one with an outside collaborator.

Cognitive interviewing – first round. The draft survey instrument was tested to assess the extent to which the questions we asked were understood as intended. We accomplished this by conducting cognitive interviews with five practicing physicians and two nurse practitioners within our academic department. The primary author watched each participant complete the survey, inquired about areas where respondents appeared to have difficulty, and asked respondents to both paraphrase what the questions meant to them, and to give some examples of the behaviors survey questions were targeting. Through the first round of cognitive interviews, we found that participants had difficulty identifying a typical collaboration; they told us there was too wide a range of collaborative behaviors to pick one as typical. Additionally, we found that clinicians were not willing to acknowledge identify problems with their own interprofessional communication unless we also acknowledged their time constraints. We revised the survey based on these findings.

First expert review: We then presented our survey and the preliminary results to a group of eighteen physicians and researchers in a 90 minute focus group format. Based on the suggestions from this group the survey was revised to ask about the participants' last collaborations involving risk and ambiguity – rather than a typical collaboration. While this change meant the individual responses would have more variability, it also meant the overall response pattern would be more indicative of the range of collaboration behaviors. We also changed the wording on the adaptation behaviors "change what you do" to "tailor your work"

which was less offensive to clinicians – changing their work content was viewed as abandoning professional autonomy and responsibility.

Cognitive interviewing – second round: We tested the revised instrument with three physicians, three nurses, and one social worker who worked in an internal medicine clinic within our university but was different from the first cognitive testing site. We repeated the process described above for cognitive interviewing, and through this process identified only one problem with the survey items: participants wanted a description of survey, with examples, on the first page. We made this change.

Participants appeared to understand the questions, and could provide examples of all of the behaviors.

Final expert review: A group of four experts in informatics, qualitative research, medicine, primary care delivery systems, and the psychology of collaboration reviewed the instrument for face and content validity – specifically if the items accurately represented the constructs, if the constructs tied to theory, and if the items covered the domain. Experts had positive feedback on the survey, confirming its content validity. However, they felt that some of the conceptual targets we set out to assess via this instrument were not completely met. To address this, we added test questions to the online version of the instrument to expand domain coverage. The additional questions covered goal commonality, mutual awareness, workflow, and shared decision-making. These questions are also included in the Appendix.

Institutional Review Board Approval

IRB approvals were obtained from the OHSU Institutional Review Board.

Validation Data Collection and Sampling

Validation testing was conducted at a community health clinic with different ownership, objectives, and systems than the clinics where the instrument was developed. This 22 provider practice has been recognized as a LEAP (learning from effective ambulatory practices) clinic by the Robert Wood Johnson Foundation.

Participant recruitment: At staff meetings we explained the survey and asked for the participation of all clinicians who were involved in developing care plans for patients (primary and urgent care providers, panel managers, behaviorists, and the clinic pharmacist). Follow-up solicitations were by e-mail. All solicited clinicians received a $10 Starbucks card in advance regardless of actual participation. No information that could be used to identify the participant was included on the survey.

Survey administration: All participants were handed a paper copy of the survey with the protocol/consent form by the primary author at the solicitation meeting. They were also sent an email with a link to the online survey. Half completed the paper version first; the other half completed the online version first. The REDCAP survey (63) tool allowed for both confidential survey collection and follow-up emails to participants who have not participated without identifying individual responses.

Data was collected from August 2, 2013 to November 8, 2013. Of the total 22 potential participants in the clinic, 21 were solicited, 20 completed both the paper and online versions of the survey, and one completed the paper version only. By having participants complete both online and paper versions we could compare the results of the two input methods and compare the results for equivalency. Paper surveys were returned to a collection box in the clinic without individual identification, REDCAP maintained the anonymity of the participants. The participants

included six medical doctors (MDs), two doctors of naturopathy (NDs - who self-identified as physicians), two physician assistants (one of whom is also an ND), six nurse practitioners (three family and three mental health), one registered nurse, three licensed practical nurses, and one pharmacist.

Data Management

Data management, exploratory analysis, and the computation of reliability statistics were conducted using R statistical software (version 2.12). (16) We performed our modeling and hypothesis testing using STATA (version 13) (48), with appropriate multi-level analysis techniques.

Analysis

We analyzed the tool for both validity and reliability. Validity testing included face, concept, construct, and convergent validation. Face validity tests to see if the items appear to measure the questions addressed, concept if the items are adequate in total to measure the domain being measured, construct if the results are consistent with the underlying hypotheses, and convergent if the results are consistent with known results. (64). A reliable survey will provide consistent measurements while a valid survey provides useful measurements of the phenomenon it purports to measure.(64) Face and content validity were demonstrated in our development process.

Construct validation: Because collaboration is not directly measurable (we are relying on the perceptions of clinicians), we tested to see if the underlying hypotheses are supported by the observed data.(64) We also tested to see if the collaboration behaviors are all related, but may consist of different constructs. We evaluated this by examining the correlation matrix (all of

the factors should be positively correlated), and by calculating Cronbach's alpha for the scale as a whole, and for each of the collaboration behaviors. Normally, the standard for homogeneity is an alpha of 0.80 or above.(44) With a small sample, however, Cronbach's alpha will be lower and our criteria for homogeneity was 0.70 or above.(64)

One possibility is that the behaviors are not only related, but that each set of behaviors is a pre-requisite for the next higher level – that trust and respect are required for communication, communication is required for coordination, and that coordination is a pre-requisite for adaptive collaboration. If this is true, the scale would be a Guttman scale. (65) The percentage of observations in which this holds true is the coefficient of reproducibility (CoR); to be a Guttman scale, the CoR should be above 85%.

Alternatively, each lower level behavior would increase the probability of a higher level behavior. In this case the behaviors would be positively correlated, and we would be able to build a structural equation model where an increased frequency of each step is associated with an increased frequency in the next higher step with a p-value of less than 0.05. The overall model would is measured by the root mean square of the estimation or RMSEA, good is RMSEA < 0.10.(46) We tested this form of the hypothesis using a path model developed using Structured Equation Modelling in STATA. (48) By using SEM, we could simultaneously test both the regression equations and the overall model fit.

Convergent validation: To show convergent validation we tested the effects of distance, a factor that is known to make a difference in collaboration(64) There is ample evidence that closer proximity increases collaboration behavior frequency, so the instrument should show significant distance effects (at least one step). (66-69) Our hypothesis to test convergent validation was that distance would decrease all of the collaborations behaviors ($p < .05$).

Unlike the results for the other three behaviors, the trust data was skewed; this required that we tested the trust results using a chi-square calculation with data in three categories – always trust, usually trust, and other; for the communication, coordination, and adaptation factors we used a t-test, adjusted for clustered data.

Adjustment for Clustered data: Since we are obtaining two to four separate observations (collocated and distant collaborators, online and paper) from each participant, the observations were not independent. As a result, we used a more robust variance estimator (adjusted for the intra cluster correlation coefficient) for both our means comparisons and a structured equation model.(47) Consistent with generalizability theory (70), this more robust model provides an allowance for individual biases not related to actual behaviors.

Reliability testing: We tested the reliability of the tool two ways. We determined the split-half correlation for all of the observations and calculated the Spearman-Brown adjusted reliability coefficient based on the split half correlation (0.80 is good, 0.9 or above is excellent).(64) In addition, seven participants completed the tool on the same set of collaborations for both their online and paper surveys. The results were compared and used to compute the test-retest reliability of the survey – both the response variability and the correlation between the results of the two surveys each test retest participant completed.

Results

Time to complete: During cognitive interviewing, the time to completion was 4.5 to 7.0 minutes for the full instrument, and 2.5 to 4.5 minutes for the collaboration behavior questions only.

Expert review: Both panels of experts agreed on the face validity of the items. The physician researcher panel was concerned with the format and the time required to complete the survey. The content experts did not find any of the items redundant. They also found that the questions were unbiased and applicable in a wide range of situations. One of the content experts was concerned about whether or not the questions would enable hypothesis testing (since resolved). The content experts also suggested four additional questions to better assure adequate domain coverage.

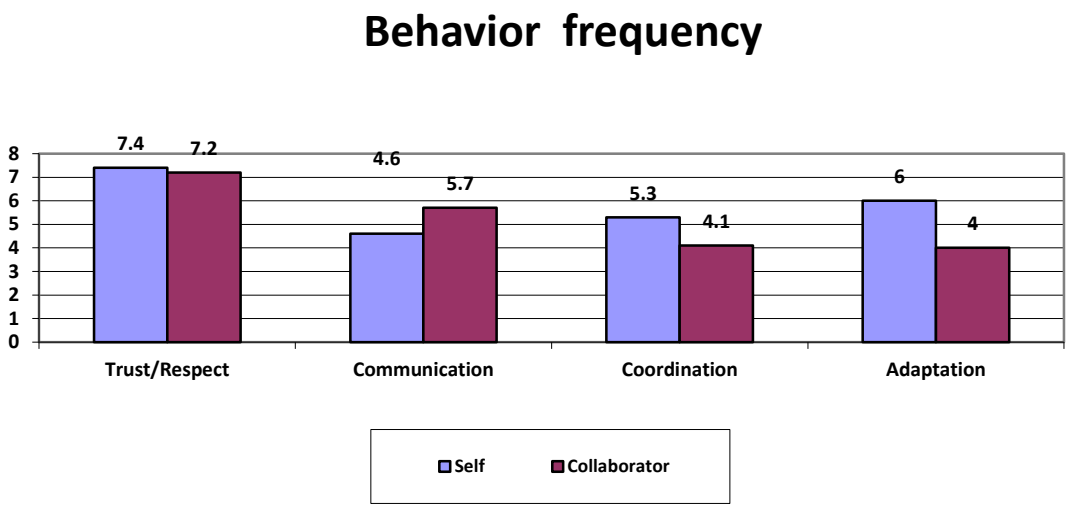
Establishing construct and convergent validity: We were able to solicit 21 of the 22 possible clinicians in our validation clinic (one was out of the clinic); all of the solicited clinicians participated. Twenty participants completed both the online and paper versions of the survey. The majority of our participants were primary care providers (PCPs). As shown in table 5.1 (next page), the most common collaborators inside the clinic for the PCPs were a behavioral health professionals – in this clinic a psychological mental health nurse practitioner who is providing counseling and psychiatric drug management to their patients; for the other roles, the PCP was the most common collaborator. Outside the clinic, specialists and care managers were the most common collaborators for the PCP's.

Collaboration behaviors: Participants reported that for most collaborations they usually or always trusted their collaborators (average 7.4 sem .19). But for communication, coordination, and adaptation the average was "sometimes" (5.25,4.7, and 5.0 respectively, sem .22 to .25) Figure 5.1 summarizes the mean responses for the validation clinic; the only statistically significant difference between self and other rankings is for the adaptation factor.

Table 5.1: Validation clinic participants and their most recent collaborators. Within clinic, PCP's were the most common collaborators, while specialists were the most common outside collaborators. Note: behaviorists were defined as psychologists, social workers, and others who primarily provide therapeutic counselling.

				Collaborator roles				
Participant role	Count	Collaborator Locations	PCP	Specialist	Care Manager	Behaviorist	Other	Total
Primary Care Provider (PCP)	12	In clinic	7	2	3	8	1	21
		Distant	1	13	3	2	2	21
Specialist	3	In clinic	2	1	1	2	0	6
		Distant	0	0	3	2	1	6
Care Manager	3	In clinic	4	0	1	1	0	6
		Distant	0	0	3	0	3	6
Behaviorist	1	In clinic	2	0	0	0	0	2
		Distant	0	2	0	0	0	2
Other	2	In clinic	4	0	1	1	0	6
		Distant	0	6	0	0	0	6
		Total	20	24	15	16	7	82

Figure 5.1: Mean collaboration behavior frequency



(9 = always, 7=usually, 5= sometimes, 3= seldom)

While the communication, coordination, and adaptation factors had approximately normal distributions, the trust factor data was right-skewed. As a result we used categorical techniques to analyze the trust data.

Construct validation- Item correlation: All of the items in the basic scale were positively correlated (Table5.2, below). Eight of the 28 possible correlations were statistically significant after adjustment for multiple hypotheses – four of these are with the "you trust" item. The perception that the other collaborator is adapting what they do to meet participant patient's needs is also highly correlated with the how often participants are willing to coordinate and communicate.

Table 5.2: inter-item correlations; bold indicates statistically significant ($p < .05$) after Sivak multiple hypothesis correction

Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7
You trust (q1)	1.0	.					
They respect (q2)	.46	1.0					
They communicate (q3)	.40	.23	1.0				
You communicate (q4)	.32	.26	.28	1.0			
They coordinate (q5)	.33	.20	.48	.16	1.0		
You coordinate (q6)	.49	.32	.28	.38	.31	1.0	
You adapt (q7)	.64	.25	.32	.28	.38	.31	1.0
They adapt (q8)	.32	.24	.14	.45	.80	.33	.45

The positive correlations indicate that there is a relationship between these behaviors despite their differences – the presence of one behavior makes another more likely.

Factor homogeneity: Item values for the both items for each behavior were combined into factor values for the eight item scale, i.e. q1 and q2 were added together to form a total trust score, q3 and q4 as communication, etc. Cronbach's alpha for the factors was between .70 and.80 (trust = .70, communication = .80, coordination = .76, adaptation = .70), but only 0.34 for the entire collaboration behavior instrument. This implies that the factors were internally homogenous, but that the each of the factors measured a different behavior.(64)

The expanded scale: In the expanded scale, three of the four additional questions (common goals, awareness, workflow, and shared decision making) were positively correlated with the trust/respect, communication, coordination, and adaptation combined scores (.23, .56, -.06, and .54 respectively). The negative correlation for workflow and coordination was not statistically significant, the awareness/communication and input/adaptation correlations were significant after the Sivak correction ($p < .01$). When we examined the expanded scale psychometrics, however, the results were different. With the common goals, awareness, workflow and input questions added the within-factor alphas decreased to from .56 to .65, but the Cronbach's alpha for the overall scale increased to .85.

The scale does not have Guttman properties: The Coefficients of Reproducibility ranged from 0.51 for coordination/adaptive collaboration to .79 for trust and communication. Trust appeared to be closest to a Guttman factor, i.e. trust is a pre-requisite for a higher-level behavior, with factors of .79, .77, and .78 for communication, coordination, and adaptation respectively.

Path modeling (structural equation modeling): The STATA implementation of SEM provides both p values for each of the relationships in the model, and statistics for the overall fit (RMSEA). An increased frequency in any factor increases the likelihood of an increased frequency in the next higher factor (figure 5.2, below:

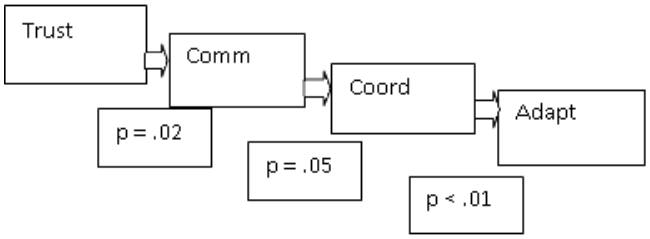


Figure 5.2: a path diagram for the factors. Each factor had a statistically significant association with the next higher factor.

By evaluating all of the equations simultaneously, we were able to evaluate our model as a whole. The model had a root-mean-squared residual (RMSEA) of .045 but a coefficient of determination of only 0.25. An RMSEA of .045 shows very good overall model fit, but a coefficient of determination of 0.25 indicated that there are probably additional factors involved.(46)

Convergent validity: To see if distance reduced the frequency of collaboration behaviors – thus demonstrating convergent validity - we tested to see if the reduction in behavior frequency was statistically significant. As discussed previously, we had to use different statistical tests for the trust /respect factor because the data was skewed. Twenty seven of the 32 "always trusted" collaborators were collocated; twenty-five of the 29 collaborators who were trusted "sometimes" or less were distance collaborators. The probability of this occurring if distance was not a significant factor is less than 0.1 percent (chi-squared = 29.59, $p < .001$).

For the other three factors, distance also affected the factor scores. In the box plots below (figure 5.3), the vertical lines connect the high and low observations, while the colored areas are the interquartile range, and the centered line is the mean.

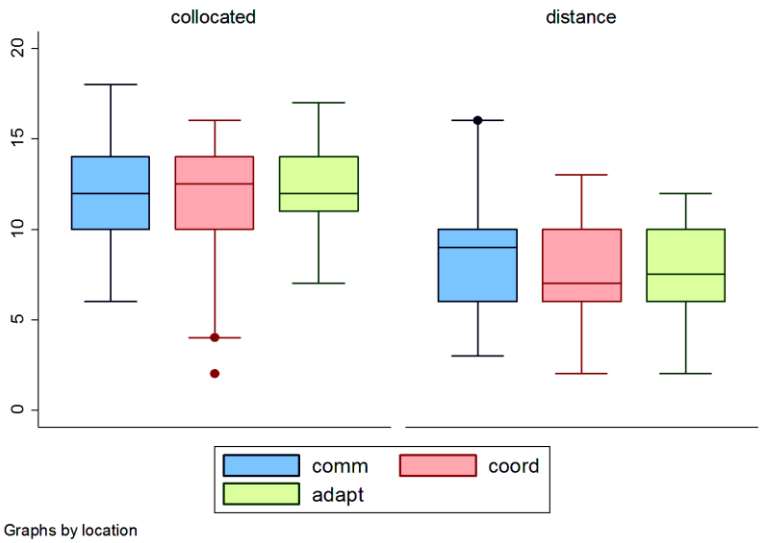


Figure 5.3: the co-located total scores (two items) for communication, coordination, and adaptation were higher that the corresponding distance scores ($p < .001$). (2 = never, 10=sometimes, 18 = always).

Reliability: The split-half difference (odd-even) for all participants was 0.51 per item (on a 1 to 9 scale), the split-half correlation was .76 (95% CI .64 to .84). The Spearman-Brown "prophesy" reliability coefficient was .91. These are good results for a sample of this size. (64)

We also checked the test-retest ratings to see if the results were different for the paper and online versions. The average difference between the aggregate online and paper test results was less than .0001 on a scale of 1 to 9 (the average item variance was 2.1 on the same 1 to 9 scale).

Discussion

The Healthcare Collaboration Behavior tool we developed appears to be brief, flexible, valid, and reliable. It can be completed in less than five minutes. It is usable in a wide range of inter-professional collaborations and could, potentially, be used to monitor the effects of several kinds of change (e.g. EHR usage, process and team building interventions, outcome measures) on collaboration.

The Healthcare Collaboration Behavior tool does not make any assumptions about whom the collaborators are. Nor does it require both sides of the collaboration to participate in the survey process. It can be used within a clinic and can also be used to provide valuable data about the collaborations outside the clinic. Because it asks about individual collaborations, it also captures a wider range of behaviors. By gathering data on at least two collaborations per participant, we can use multi-level analysis techniques to allow corrections for individual bias, increasing validity.

The expanded version of the scale provides better domain coverage, while the basic (eight) item version appears to have slightly better psychometric properties on a factor level.

This survey tool produces useful, consistent results. It has good split test reliability and can be administered in an online paper version with minimal bias. With the basic version, three of the four factors approximate a normal distribution, and can be analyzed accordingly (the trust/respect behavior is positively skewed and must be analyzed using ordinal or categorical methods). The expanded version is significantly less skewed and, depending on the actual data distribution, may be amenable to interval statistics.

As a natural experiment, however, this validation study is exposed to multiple possible confounders – differences in patients served across providers and clinics, variations within roles within clinics, and differences in social hierarchy. One possible confounder – and one that might invalidate our convergent validation, is the difference in type of collaborator. For this sample within-clinic collaborators are more likely to be PCPs or Behaviorists, while distant collaborators were more likely to be specialists. We tested to see if the distance effect was really due to the differences in roles by adding the collaborator's role as an additional categorical level in our regression analysis. We found that the role effects were not significant ($p = .31$) but distance was still significant ($p < .001$).

Further uses

Our instrument only measures the frequency of the behaviors, it does not attempt to diagnose the reasons collaboration behaviors increase or decrease. But it is brief enough that it can be easily combined with another instrument that focuses more on the antecedents of collaborative behaviors.

By allowing the measurement of separate behaviors, the tool will permit us to tie the improvement in outcomes to changes in specific behaviors. We believe it is distinctly possible that efficiently and effectively treating an ankle sprain may require only trust and limited

communication, while managing refractory diabetes in a patient with multiple co-morbidities may require significantly more frequent – and more complex – collaboration behaviors.

The instrument can also be used to monitor the effectiveness of a wide range of interventions – these might range from team-building activities (both within and without the clinic), to shared goals and incentives, to improved data sharing over time.

LIMITATIONS

This tool is based on clinician perceptions of just two collaborations. As such it is a valid tool in for evaluating groups of collaborations, but not for evaluating one individual collaborator who would (hopefully) be involved in many more collaborations. It was developed in one setting and validated in a second, but will need to be tested in additional settings to demonstrate its generalizability. It focuses on behaviors and not the conditions that are conducive to collaboration; as such we would anticipate its use in conjunction with other tools to plan and evaluate interventions. Further, there are many other possible confounders in determining collaboration, and these must be considered when evaluating the generalizability of our results.

CONCLUSION

This survey fills the need for a profession and behavior neutral instrument to measure the frequency of collaboration behaviors within and outside the clinic. We hope that others will adopt it and use is as one of the tools in their research.

Chapter 6: The EHR, other communication channels and healthcare collaboration behaviors

(to be submitted to JAMIA or JGIM on acceptance of chapter 5 in a peer-reviewed publication)

Abstract

Background: With the implementation of electronic health records (EHRs), clinicians have more choices for how they communicate, but it is unclear how this influences collaboration between clinicians.

Hypothesis: Increased use of the EHR will be associated with more frequent communication and coordination behaviors, but will be negatively associated with trust and adaptive collaborative behaviors.

Sample: 74 clinicians in eight Oregon primary care clinics implementing a patient centered medical home model.

Methods: Each participant used the Healthcare Collaboration Behavior tool to rate two recent significant collaborations, one within and one outside the clinic. Data were also collected on the use of communication channels in these collaborations. Communication channels were aggregated through principal components analysis (PCA) into three categories. Relationships between the type of communication channels and four collaboration behaviors (trust and respect, communication, coordination and adaptive collaboration) were evaluated using multi-level regression.

Results: PCA analysis found three principal differentiating factors: use of the EHR as a communication channel (chart notes, messages, and secure email), voice-based communications use (meeting/telephone) and use of other channels (text, email, and fax). Consistent with our hypotheses, more frequent use of the EHR was associated with increased communication and coordination behaviors ($p<.001$), but not adaptive collaboration. Increased

use of voice-based communications was associated with more adaptive behaviors ($p < .001$). Use of the EHR did not resolve the challenges of creating trust across distance.

Conclusions: Basic communication and coordination activities are supported by the EHR, while other in-person or telephone communications are needed for more complex, adaptive collaboration.

Introduction

Changes in the healthcare environment and technology, particularly the electronic health record (EHR) are changing primary care delivery. The triple aim of improved population outcomes, higher patient satisfaction, and increased efficiency – is driving a number of these changes in the U.S.(1,71) According to the Institute of Medicine, meeting the triple aim will require increased communication, coordination, and collaboration between providers. (1) The patient-centered medical home (PCMH), a re-envisioning of the primary care practice, attempts to support the triple aim by providing accessible, comprehensive, coordinated, and relationship centered care.(72,73) At the same time these clinics are also working to effectively implement the electronic health record; experts agree it is an essential part of the transformation to the PCMH. (5)

These PCMH clinics are a rich environment for studying communication and collaboration behaviors. The goal of the team-based PCMH transformation is to improve efficiency, patient satisfaction, and patient outcomes. Collaboration research predicts that bringing clinicians together as teams will improve performance, so the PCMH clinics are trying to improve collaboration, both within and without the clinic walls.(6) In practice, the improvements are just

beginning to be seen.(74) An open question, though, is how to improve collaboration with specialists who are not located in the clinic.

We have known for some time that distance is a barrier to effective collaboration.(66,67,69) Co-located clinicians have a wide array of informal communication channels available to them that are not available in collaborations over distance– hallway and cafeteria conversations, cross-talk within shared workspaces, etc. These channels are richer and more immediate than those available to separated (distant) collaborators.(66,75) and can help build common ground. Common ground is the set of shared data, mutual understandings, and common references that facilitate communication and collaboration.(66) Increased common ground in turn, can enable more efficient communications, creating a virtuous cycle.(76,77) In addition to building common ground, co-located collaborators can use richer channels – allowing communication of both affective and intellectual data.(68,78) These richer channels also allow more immediate clarification and feedback. The higher level of communication is particularly important for tightly coupled work – work that requires adaptation and close coordination.(79) Developing care plans for complex cases is one potential example of tightly coupled work between the primary care provider and specialists.

We cannot expect co-location to solve the collaboration and communication issues for the 45% of U.S. office visits that occur outside the primary care setting.(80) Technology, however, may be able to mitigate some of the collaboration barriers due to distance.(68) By providing more rapid feedback between collaborators, multiple channels, and the ability to provide more personalized, nuanced information, some of the barriers to collaboration across distance could be reduced. One of the evolving communication channels is the EHR. Our earlier qualitative

work, and the qualitative work of others, has found that the performance of the EHR as a support for collaboration is mixed.(21,22,81)

This mixed performance may be due to the variation within collaboration behaviors themselves. In our previous work we found that there were at least four different collaboration behaviors – trust, communication, coordination, and adaptive collaboration (adaptation). Trust is a willingness to rely on the work of others.(45) Poor quality documentation in the EHR reduced trust.(21,22,41,81) While there are a large number of definitions for communication; in this case we mean the exchange of information needed to perform a clinician's task. Using an EHR can make it very easy to for a clinician to think they are communicating, but too often their message is lost or buried in a "haystack" – resulting in a communication illusion.(56,81) While the EHR has significant potential, it is very incomplete in its support of coordination activities. Finally, adaptive collaboration is changing the content of the tasks(41) – tailoring the work to better meet the needs of the patient or the care team. The EHR was not sufficient, by itself, to support this behavior.(81) We developed and validated a tool, the Healthcare Collaboration Behavior survey, to measure the frequency of these behaviors in collaborative relationships.

In this quantitative study, we use a novel, validated tool(82) to compare the reported frequency of collaboration behaviors with the use of the EHR and other available channels.

Methods

Hypothesis: Our hypothesis, based on our earlier qualitative work, is that the increased use of the EHR should be associated with increased levels of communication and coordination, but not adaptation. We also explore the associations between the frequency of alternative communication channel usage and the four collaboration behaviors.

Sampling: Survey data was obtained from the eight primary care clinics participating in the TOPMED (Transforming Outcomes for Patients through the Medical home Evaluation and reDesign) trial. The TOPMED trial is a pragmatic cluster-randomized controlled trial that compared different incentives, practice facilitation approaches, and IT support and their effect on the triple aim outcomes of health, cost, and patient experience. The trial was based on PCMH principles, and clinics all had facilitation, care coordination, and informatics assistance provided to them as part of the trial. They were selected to represent a range of clinic sizes (three to thirty providers), urban and rural locations, and four different EHR providers.

Measures: We developed and validated (22) the Healthcare Collaboration Behavior tool, a survey instrument that had two primary parts. The first part measured the frequency of collaboration behaviors. Participants were asked to think about their two most recent significant collaborations, and rated the frequency of the collaboration behaviors (trust/respect, communication, coordination, adaptation) that occurred. This approach provides data on the range of collaboration behaviors, but must be aggregated to establish typical practices. Participants rated the frequency of collaboration behaviors in four categories: trust/respect, communication, coordination, and adaptation from never (scored as a 1) to always (scored as a 9). Three items were developed for each factor; possible collaboration factor scores then ranged from 3 to 27. The collaboration tool validation was previously discussed in Chase et al.(82) The items for this part of the tool can be found in Appendix 1.

The second part was designed to measure the frequency of individual communication channel usage in these collaborative relationships. It is based on the channel selection and frequency of usage tools developed by the Beitz, Olson et al in their Collaboration Wizard (43). In this tool participants were asked to rate their frequency of use of a given communication channel on a

nine point scale from never to always. In addition to the nine listed channels that emerged from our cognitive interviewing (informal, or ad hoc, in-person discussions; telephone calls; formal meetings; fax; EHR chart note; EHR message; secure email; other email; text message; and multidisciplinary meeting), participants were given the option to indicate other channels used. Face validity was established in a cognitive interviewing process with clinicians in the OHSU Geriatrics and Internal Medicine clinic (face value), and content validity was established through expert committee review.

The survey instrument also included questions on the participant's profession and roles, on the roles of their collaborators and open-ended questions "What else can you tell us about collaboration in your clinic?"/"What else can you tell us about communication in your clinic?"

Institutional Review Board Approval. The OSHU Institutional Review Board approved this study.

Participant recruitment: The inclusion criterion was professionals who created or modified patient care plans. Participation in this survey was voluntary, but encouraged by the clinic leadership teams. Potential participants were given a five dollar Starbucks gift card on solicitation, participation was not required to receive the gift cards. Where possible the initial solicitation was made at a clinic provider or team meeting. Follow-up solicitations were made by email.

Data collection: Clinics could choose whether or not to complete the survey on paper or online. Half of the clinics elected to use an online survey tool (63), and completed paper surveys. In our validation process we demonstrated the equivalence of data collected in either form.

Data analysis: The data was pre-processed and aggregated using the R statistical language (version 3.0.2). The paper data was input twice and any differences were compared to the

original survey. It was then analyzed using the STATA statistical software package, version 13.(48) Missing data was excluded on a pairwise basis. After initial descriptive statistics, we extracted patterns in channel usage using principal components analysis (PCA). Principal components analysis determines what factor combinations best explain the variance within the observations. The initial results from the PCA analysis were rotated obliquely (Promax) to maximize the probability of distinguishing the different components.

We then tested these components for their effects on collaboration behaviors. Since each participant rated both an internal and an external collaboration – and because and multiple clinicians responded from each clinic, their responses were not independent. As a result the data was treated as clustered data, with two levels of clustering – the individual respondents and their clinics. Through the use of multi-level regression we were able to adjust for both clinic level effects (top level) and the individual biases (second level) that presented threats to independence. For the multi-level estimation of the factor effects, then, the estimate was based on:

Obs (for each factor) = $\mu_{ind} + \mu_{clinic} + \Sigma\beta_i * x_i + e$

Where μ_{ind} and μ_{clinic} are the individual biases and the clinic effect, β_i and x_i are the estimated effect and frequency of channel i.

We used the maximum likelihood estimation (MLE) option for our analysis – this returns parameter estimates that maximize the probability of the observed results based on the assumed distributions. We assumed that the communication, coordination, and adaptation factors would approximate a normal distribution, and that the trust factor could be divided into three levels with a corresponding multinomial distribution. These assumptions were verified prior to continuing with the analysis. Prior to making this multi-level estimate, we used a

stepwise regression without level effects to determine candidate channels with significant effects. Once these candidates were developed we then used the multi-level regression to confirm the effects.

Results

Participation: Two-thirds of the participants (Table 6.1)were primary care providers and the remaining participants were divided between care managers and other participants (e.g. pharmacists, acupuncturists, nurses other than care managers). Just over half of the participants came from two large clinics.

Clinic	Primary care providers	Care Managers	Others	Total	Estimated Percent Participating
A	1	1	0	2	50%
B	15	6	3	24	75%
C	14	3	7	24	80%
D	2	0	0	2	25%
E	7	1	0	8	75%
F	2	1	0	3	40%
G	4	0	1	5	60%
H	5	1	0	6	50%
Total	50	13	11	74	71%

Table 6.1: Participation by clinic and role

Within the clinics, the participants identified 28 PCPs and 29 Care Managers as their most recent collaborators. Externally, specialists comprised half (37 out of 74) of the distance collaborators.

Communication channel usage by collaboration type (in clinic vs. distance)

The bars in figure 6.1 below and the next two figures represent the inter-quartile frequency of communication channel usage for in-clinic compared to distance collaborations; the center line

is the median frequency. Dots represent outliers. Collaborations within the clinic were more likely to use informal (average 6.9 of 9, or 'usually') communications than distance collaborators (average 2.4 of 9, or seldom; $p < .001$), while outside the clinic collaborations were more likely to use written (letter/fax) communications (average 4.2 for collaborations over distance, but 2.7 for collaborations within the clinic $p<.001$).

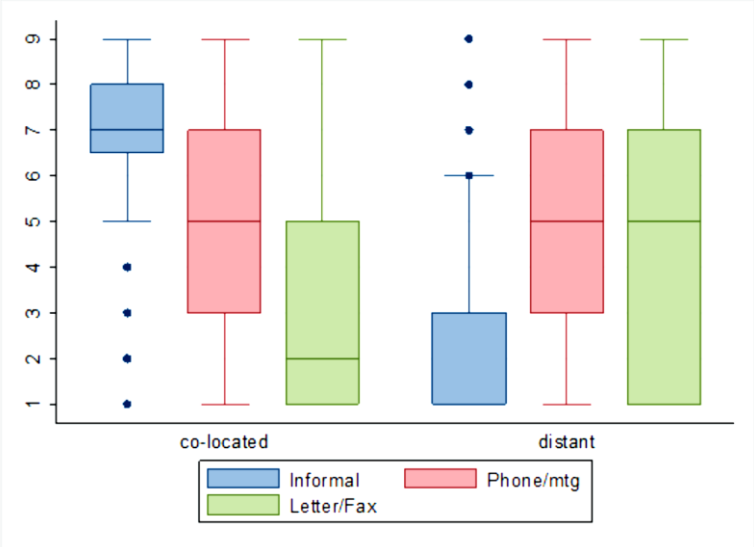


Figure 6.1: Frequency of non-EHR communication channel usage for co-located and out of clinic. Within the clinic informal (ad hoc or meeting communications were most frequent, while phones/formal meetings and written communications were the dominant channels for collaboration between locations (1 = never, 3= seldom, 5= sometimes, 7= usually, 9 = always

As shown in figure 6.2, below, clinicians used an EHR and secure email to communicate more frequently within the clinic than between clinics ($P < .001$ for all three channels).

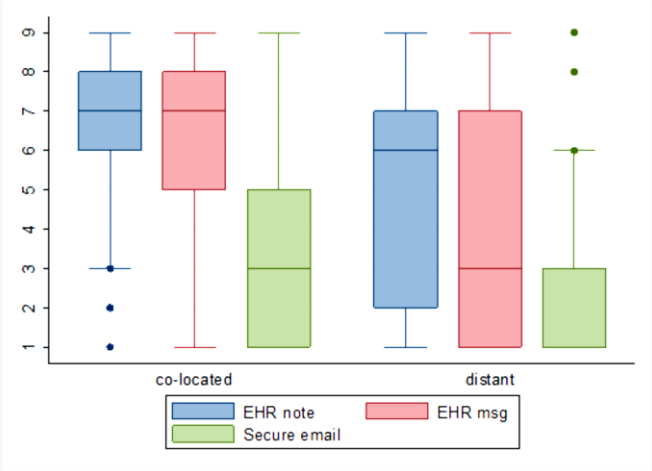


Figure 6.2: Frequency of EHR/secure communication channel usage for co-located and out of clinic collaborations. Clinicians were more likely to use the EHR to communicate with in-clinic than distant collaborators

1 = never, 3= seldom, 5= sometimes, 7= usually, 9 = always

Non-secure email and texting were used very seldom with in the survey group (median frequencies 1.7 and 1.4 where 1= never, 3 = seldom). Multi-disciplinary team meetings (figure 6.3, below) occurred more frequently for within clinic collaborations ($p < .001$), although use was seldom.

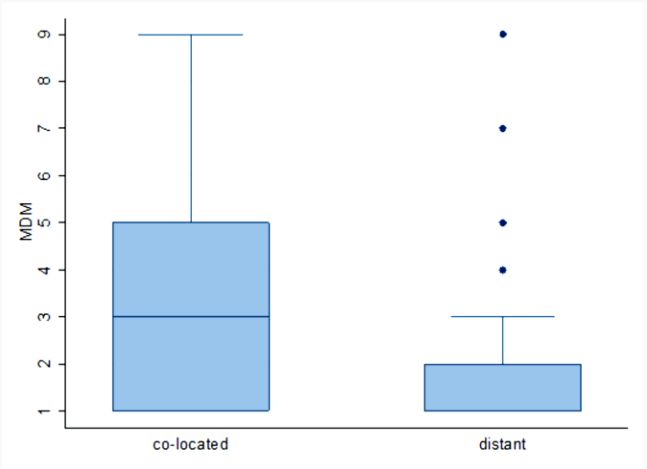


Figure 6.3: Frequency of multi-disciplinary team meetings for co-located and out of clinic collaborations. 1 = never, 3= seldom, 5= sometimes, 7= usually, 9 = always

Principal components analysis

The principal components analysis revealed three main factors: EHR-mediated communications (C1: EHR usage); telephone, fax, and secure emails (C2: voice-based); and the use of other emails and texting (C3: non-secure channel usage). All of these factors had eigenvalues greater than one, the KMO statistic for the three factor was 0.69 (a "middling" approximation to the data, a 0.70 would have been "good." (70) More details on the principal components analysis are included in the Appendix.

Relationship between communication components and collaboration behavior frequencies

We examined the relationship between the frequency of a communication component and the frequency of each of the four collaboration behaviors using a multi-level regression analysis. In this analysis we included distance as a possible confounder. Distance, the use of the EHR, and voice/meeting communications affected each of the four collaboration behaviors differently (summarized in table 6.2, below).

Table 6.2: Effects of communication factors on collaboration behaviors

Collaboration behavior	Communication factors affecting behavior	Change in behavior per unit increase in component usage (95% confidence interval)
Trust and respect	None; only distance had an effect	-1.93 less if distance (from always to sometimes) $p < .01$, but confidence interval is not meaningful (categorical data rather than interval)
Communication	C1 (EHR usage)	.27 (.15 - .42)
Coordination	C1 (EHR usage – distance collaborations only)	.16 (.04-.28)
Adaptive collaboration	C2 (voice-based communication)	.53 (.34 - .72)

As shown above, trust was largely determined by location. Physical separation decreased trust/respect; after adjusting for the distance confounder none of the communication components made a statistically significant difference (being physically separated, on average, dropped trust and respect by 1.9 steps (from “always” to “usually).”

The EHR enabled basic communication both within and without the clinic – after adjusting for distance none of the other channels mattered. The increase was .27 “steps” in reported collaboration per step increase in the EHR usage frequency.

The EHR had only modest effects on coordination. For coordination outside the clinic (regressions including within clinic collaborations did not converge) there was a slight improvement of .16 steps per step increase in the EHR usage frequency. While distance was negatively associated with adaptation behaviors, increased use of the factor 2 (voice-based communications) could partially offset the distance effects. The differences were an increase of .5 steps per step increase in the voice-based communication factor.

Effects of individual communication channel usage on collaboration behaviors

As an exploratory analysis, we also used a multi-level regression (collaborations nested within individuals within clinics) to detect changes in collaboration behaviors associated with the use of individual communication channels. Table 6.3, below, shows the increase in the collaboration behavior factor associated with a one-step increase (e.g. from “sometimes” to more than “sometimes but less than usually”) in communication channel use.

Table 6.3: Regression results: communication channels associated with a change in communication frequency. First number is increase in behavior corresponding to increase in channel usage, unadjusted p value in parentheses. Bold results are significant after multiple hypothesis correction.

	Trust	Communication	Coordination	Adaptation
Informal	**.41 (.001)**	▪	▪	**.54 (.001)**
Telephone or meeting	▪	▪	▪	.39(.011)
Fax or letter	▪	**-.43(.001)**	▪	▪
EHR progress note	-.22 (.078)	▪	▪	▪
Message or flag within EHR	.35 (.006)	▪	▪	**.43 (.003)**
Secure email	▪	▪	▪	▪
Other email	▪	▪	▪	▪
Text message	▪	▪	▪	▪
Multi-disciplinary meeting	▪	.43 (.005)	**.21 (.003)**	**.60(.003)**

Discussion

The results of this study confirm the hypotheses we developed from our earlier qualitative work; (81) Increased use of the EHR is associated with an increased frequency of communication (basic information exchange) and coordination, but not the more complex work of adaptive collaboration.

For the three-factor model (table 2) shown in the preceding section our analysis had an estimated type II error (not detecting a true result) probability of 0.19 – we are reasonably confident it identified the significant factors. For a nine channel hypothesis testing (table 3), however, the probability of a type II error is 0.48. (28) Where the individual results were significant (especially after multiple hypothesis adjustments) they would likely remain significant with a larger sample. The non-significant relationships (shown in table 3 as asterisks) however, might have been significant if we had a larger sample. Moreover, the data on individual channels suggest but does not prove that how the EHR is used is important. If the chart note is sent without a message or flag explaining what is needed, it may result in a decrease in communication. But if it is combined with a note focusing on what is important it may increase perceived communication.

For loosely coupled tasks (79) – i.e. routine treatment, it is likely that the EHR is an adequate channel for communication. For more complex tasks however, richer communication channels (e.g. multidisciplinary meetings) may be required. More research is needed to distinguish between conditions requiring more collaboration and those that can be effectively treated using loosely coupled approaches. Since not all clinicians can attend in-person meetings, PCMH's will also need to implement richer communication channels (e.g. video conferencing).

Our results are also consistent with Graetz, Reed, Rundall et al.(83) Their study, which included over 1,000 clinicians in the Kaiser Permanente system, found that after 6 months of EHR use, clinicians believed that information available to them was more timely and complete, and that they had a better understanding of the care plans. They did not, however, report an increased understanding of roles and responsibilities.

Using multiple and/or richer channels can take time. Future research may explore how to facilitate matching the channel to the expected behaviors in order to improve collaboration.

Limitations

The questionnaire was developed and validated(82) among Oregon primary care clinics in the process of implementing patient centered medical homes (PCMH). All of the clinics in this study were also in Oregon and in the process of implementing the PCMH. We are also relying on the perceptions of the clinicians surveyed rather than observational data. It is also possible that, with more participants, the power of the study would have increased and there would have been additional statistically significant relationships.

Conclusions

Providers and systems need to be mindful of how and when they use the EHR; it is one of many communication channels and they need to consider what collaborative behaviors are needed to care for the patient in front of them. As we learn more about what collaboration behaviors are needed in the PCMH and the medical neighborhood, this data could help clinicians and organizations choose the appropriate channel for a given situation.

Chapter 7 – Discussion

Summary of findings

We have shown that the use of the EHR is associated with changes in collaboration behaviors and that it is possible to measure these collaboration behaviors. What we have not yet shown is whether an increased frequency of collaboration behaviors is a positive change, nor have we shown that there is a casual link between EHR usage and these changes.

But we have laid a foundation. We have shown that collaboration behaviors can be measured and areas for improvement identified. In this dissertation the trust/ communication/ coordination/adaptation model appears to be borne out in practice. We found in our interviews, observations, and survey data that there was a wide range of responses for all of the behaviors. Further, we found that while these behaviors were distinct, if one behavior is present, others will be more likely. Although the models we build were statistically significant (RMSEA < .05), it is likely that there are other, confounding factors that also play a role in triggering collaborative behaviors (GOF < 0.95).

We found that using an EHR does have an effect on collaboration behaviors, and that the EHR plays different roles in this process. The different roles have varied, often mixed effects. Important effects include: poor quality documentation reduces trust; the false illusion of communication can create misunderstandings and even failures in the transmission of critical data; templates, order sets and bundles have significant potential for increasing coordination; the EHR can provide a common data set that establishes common understanding; and the EHR can't replace talking for adaptation purposes. In our qualitative work we also found that both implementation processes and role maturity also affect collaboration behaviors.

Finally, we found that there are associations between the choice of the EHR or other communication channels and the frequency of collaboration behaviors. For example, those that engage in more adaptive behaviors are more likely to talk to their collaborators. It is possible that providers choose communication channel based on behaviors they are trying to support, rather than the channel dictating the behaviors. When we aggregated communication channel usage into three different factors (based on PCA) – EHR usage, voice, and other (fax, text, letter) increased EHR usage seems to be linked to increased frequency of communication behaviors and better coordination across distance. But meetings or phone conversations were needed for adaptive behaviors. Although we were underpowered for analysis of all nine channels independently, we were able to find four tantalizing clues on individual channel effects: 1. Informal communication has significant effects on trust and adaptation; this is true even after adjusting for distance effects. 2. Reliance on faxes is associated with less effective communications. 3. Sending a message or a flag with the copy of the EHR progress note is associated with higher frequencies for trust and adaptation; sending an EHR progress note without an additional flag or explanation reduces trust. 4. Multi-disciplinary meetings were associated with better communication, coordination, and adaptation.

The results of the qualitative and quantitative analyses are similar. Although conducted with different methodologies at different sites, both studies show negative associations between dependence on progress notes for communications and trust, more frequent communications with an EHR, better coordination over distance with an EHR, but did not show that an EHR increased adaptive behaviors. This triangulation supports our conclusion that the effects of the EHR on collaboration behaviors are mixed.

Strengths and weaknesses of this dissertation

This dissertation makes several contributions to the field. It is the first multi-site, multi-system study on this topic, providing further evidence of potential generalizability. Our sites had a wide range of sizes, different ownership structures, a used a variety of EHR systems, and were located in multiple geographic regions of the United States. Combining both quantitative and qualitative methodologies, the similarity of results from different methods (triangulation) supports the validity of our findings. It provides a brief, unbiased tool for measuring collaboration behaviors, the development of which involved multiple iterations with physicians, nurses, social workers, researchers and pharmacists providing thoughtful input. The novel use of multi-level regressions to control for individual biases adds to the validity of our results. Finally, the team involved in this research brought together diverse backgrounds, significant expertise, and a wide range of skills.

Limitations and Issues

The study does have limitations. It was focused on primary care in the United States and so may not be generalizable to other sites. Our limited sample sizes did reduce the power of our analysis. We were not always able to go to saturation at individual qualitative sites (although the results from the five sites were very similar). There was a limited sample size for validation, especially test-retest data. For our third aim – the associations between EHR usage and collaboration behaviors we were limited to examining three factors, and could only peek at the potential effects of individual channel usage.

There are other issues with the potential uses for our work. The delivery of healthcare is a complex process, and there are a number of potential factors that we could not include in our analysis. Some (age, sex, when trained) we omitted in order to maintain confidentiality. Others, like the effects of specialty for outside collaborators, we simply did not have an adequate sample size to evaluate the effects. We did, at the request of two of our clinics, try to expand the use of this instrument to medical assistants. The instrument simply did not work for medical assistants; most were unable to identify the collaborators and the types of behaviors. One clinic leader wanted to use the tool to evaluate the performance of individual clinicians; this tool is not appropriate for that purpose as it only measures the most recent two collaborations. Nor does it show whether the level of collaboration is good or bad. The instrument just reports the frequency of certain behaviors. And finally, it is not prescriptive. The survey does not provide any guidance in how to increase the frequency of collaboration behaviors.

Comparison with other published work

This is an emerging field of study; there are a limited number of studies on the interaction of the EHR and collaboration. We found three other qualitative studies on this topic,(21-23) with similar findings (see Chapter 4). However, ours is the first multi-site, multi-system study focusing on the effects of the EHR on clinician collaboration.

The instrument we developed is also novel. There are a large number of instruments developed to measure collaboration/coordination behaviors.(27) Ours is unique in that it 1) works both within and without the clinic, 2) has been validated with more than two professions, and 3) is not based on prescriptive theory. As discussed in Chapter 5, Valentine(59) found only two published surveys that were both validated and purported to measure collaboration behaviors

within and without the clinic. One was limited to nurse-physician collaborations, and the second was based on relational coordination theory.

Gittell's Relational Coordination Survey (61) measures relational coordination using constructs similar to those we developed independently (communication – accuracy, frequency, and timeliness, problem solving, shared goals, mutual respect). It does not differentiate between coordination and adaptation, but does provide additional dimensions for the communication. In its validated version, (62) it is used by participants within one organizational unit to evaluate collaboration with another unit. There is no self-rating, and both sides of the collaboration must complete the survey to examine any two-way effects. This survey has been used in a variety of settings, from airlines to in-patient orthopedic practices. An adaptation of this survey was used to examine the collaboration between general practitioners, nurses, and diabetes educators in Australia.(24) Unfortunately this adaptation was not validated, nor were any statistical measures provided to evaluate the significance of their findings.

The tool we have developed is more flexible than Gittell's relational coordination (RC) measure:(62) it allows the participants to specify who they are working with, it does not require both sides of a collaboration to contribute, and it allows for bias adjustment with multi-level techniques. It also captures the full range of collaborations rather than a typical collaboration. And it is not based on any theory of what is good or bad.

But the RC measure has its strengths as well. It does not involve self-rating and the potential for bias inherent in self-rating, it has over a decade of application with normed data available, and it has been shown to work with front office and other non-clinician functions. It also provides a summative measure; our tool does not do this.

Meaning of the dissertation

Our work on the effects of using the EHR as a communication channel is unique and we hope makes a contribution to the literature. The combination of techniques and multiplicity of sites allows for triangulation of our findings. We believe that the three studies combined constitute a strong argument for the generalization of our findings to other clinics implementing the patient-centered medical home. As such, it should be a platform for future work.

This dissertation developed, and demonstrated the use of a tool to monitor the effects of the EHR and other potentially disruptive innovations on collaboration. By doing so we can identify areas where better EHR design or implementation processes are needed , show where EHR (or other innovation) is not effective, and provide guidance as to when clinicians should use other tools/channels. This dissertation has not shown when the extra effort and time needed for collaboration pays off in terms of improved outcomes, increased efficiency, or greater satisfaction. Nor have we demonstrated what changes will result in increases in collaboration behaviors. But it does provide tools and methods needed for future work that explores these areas.

This future work should include an analysis of the types of collaboration behaviors that result in better outcomes, the technologies that best support these behaviors, and how other elements of the healthcare delivery system affect the frequency of collaboration behaviors. One hypothesis is that there are some collaborations where the increased costs of collaboration activities exceed the potential benefits; we need to know this before we decide to invest clinicians time in collaboration activities. There is also limited data on which EHR features/implementation processes are associated with higher frequencies of which collaboration behaviors? And a third question is how do the "confounders" – differences in role,

in training, in location, and in age affect collaboration behavior frequency and communication channel usage.

This dissertation is a first step in learning about the interaction of collaboration and the EHR.

Chapter 8 – Conclusions

American healthcare is changing. In this dissertation, we have discussed the how the implementation of the EHR is interacting with the change to more collaborative delivery of primary care. There are other changes taking place, notably the move to more patient empowerment/shared decision making and the increasing complexity of evidence based medicine. The EHR will be central to allowing primary care providers adapt to this new, more complex environment.

The EHR will be central to practice adaptation only if it is modified to meet these demands. As the levels and patterns of collaboration needed within and outside of primary care clinics becomes more clear, the demands for the designers to adapt the EHR to better meet these needs will become stronger. And with that adaptation, we will gain a better understanding of what the EHR can and can't do.

As we have shown in this dissertation, the EHR has mixed effects on collaborative behaviors. It will be increasingly important to identify which effects are favorable, can be tolerated or ameliorated outside the EHR, and which must be fixed. Healthcare systems whose EHRs support their mission more effectively will gain competitive advantage; EHR vendors that make more effective systems will gain market share.

This dissertation is a start at building the tools necessary to find what works and what doesn't in collaboration and in the use of the EHR as a support system for collaboration. But much needs to be done before either healthcare collaboration or the EHR can realize their promise.

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