Summary Report

Incorporating Health Information Technology Into Workflow Redesign

Prepared for:
Agency for Healthcare Research and Quality
U.S. Department of Health and Human Services
540 Gaither Road
Rockville, MD 20850
www.ahrq.gov

Contract No. HHSA 290-2008-10036C

Prepared by:
The Center for Quality and Productivity Improvement (CQPI), University of Wisconsin–Madison, Madison, WI

Co-Principal Investigators:
Pascale Carayon, Ph.D.
Ben-Tzion Karsh, Ph.D.

Project Manager:
Randi Cartmill, M.S.

Project Consultants:
Patricia Flatley Brennan, R.N., Ph.D., F.A.A.N.
James Walker, M.D., F.A.C.P.

Project Staff:
Peter Hoonakker, Ph.D.
Ann Schoofs Hundt, Ph.D.
Daniel Krueger
Teresa Thuemling, B.S.
Tosha Wetterneck, M.D.

***Programmers*:**
Pratima Kolan
Rajiv Vaidyanathan

Project Assistants:
Bashar Alyousef, M.S.
Viveka Boddipalli, M.D.
John Capista, B.A.
Yessenia Donato
Manuel Crespo Peña
Matthew Ollila, B.S.

AHRQ Publication No. 10-0098-EF
October 2010

Agency for Healthcare Research and Quality
Advancing Excellence in Health Care • www.ahrq.gov

HEALTH

Suggested Citation:
Carayon P, Karsh B-T, Cartmill RS, et al. Incorporating Health Information Technology Into Workflow Redesign--Summary Report. (Prepared by the Center for Quality and Productivity Improvement, University of Wisconsin–Madison, under Contract No. HHSA 290-2008-10036C). AHRQ Publication No. 10-0098-EF. Rockville, MD: Agency for Healthcare Research and Quality. October 2010.

None of the investigators has any affiliations or financial involvement that conflicts with the material presented in this report.

This report is based on research conducted by The Center for Quality and Productivity Improvement (CQPI), University of Wisconsin under contract to the Agency for Healthcare Research and Quality (AHRQ), Rockville, MD (Contract No. HHSA 290-2008-10036C). The findings and conclusions in this document are those of the author(s), who are responsible for its content, and do not necessarily represent the views of AHRQ. No statement in this report should be construed as an official position of AHRQ or of the U.S. Department of Health and Human Services.

The information in this report is intended to help clinicians, employers, policymakers, and others make informed decisions about the provision of health care services. This report is intended as a reference and not as a substitute for clinical judgment.

This report may be used, in whole or in part, as the basis for the development of clinical practice guidelines and other quality enhancement tools, or as a basis for reimbursement and coverage policies. AHRQ or U.S. Department of Health and Human Services endorsement of such derivative products may not be stated or implied.

Contents

Tables

Figures

Appendixes

Executive Summary

Introduction

Health information technology (health IT) applications, which provide computerized clinical information to health care providers and/or patients, have been viewed as facilitating improved to health care quality, enhanced patient safety and streamlined administration. The pace of health IT adoption in U.S. health care organizations will likely increase, owing in part to government incentive programs and pressures from purchasing groups and consumers.[1-8] Evaluations of the impact of health IT on quality and safety show mixed results, however. The main reasons seems to be a lack of integration of health IT into clinical workflow in a way that supports the cognitive work of the clinician and the workflows among organizations (e.g., between a clinic and community pharmacy), within a clinic and within a visit. It is clear that if health IT is to provide optimum performance, it must be designed to fit the specific context in which it will be used, specifically practice and patient types. The purpose of this project is to develop a toolkit to help small and medium-sized outpatient practices to assess their workflows and to successfully implement health IT. Small and medium-sized practices are likely to need the most help in analyzing their workflows as they typically do not have access to IT support and quality improvement resources.

In this project, our team of human factors engineers, physicians, and project staff has examined existing research related to the impacts of health IT on workflow in outpatient settings and how health IT can be used to assess workflow in these settings. We have also identified currently available resources for workflow assessment in health care, as well as proven workflow analysis methods and instruments used in the fields of human factors and ergonomics, and industrial and systems engineering that could be applied in health care settings. We have synthesized the information gained into a toolkit that explains the importance of analyzing workflow when implementing and using health IT applications, summarizes commonly used methods for workflow assessment, explains the purpose of each method, describes how to implement the methods, explains the advantages and disadvantages of each approach, cites available resources for more in-depth information on each tool, and provides stories drawn from the literature and other sources that describe the experiences of small and medium-sized practices in implementing health IT.

Literature Review

Introduction

Grounded in the UW-Madison Systems Engineering Initiative for Patient Safety (SEIPS) Model of work system and patient safety,[9] our literature review analyzes (1) how health IT for ambulatory health care delivery systems can impact workflow in small and medium-sized practices and (2) how health IT can be used to study workflow in these practices. We found that most research on health IT is not focused directly on workflows within health care organizations, and studies discussing workflow vary substantially in how much information they provide on process changes.

In evaluating the literature, we have identified several types of measures and classified these according to the amount of information each provides on changes in work processes. One such type is *proximal measures*, which describe explicitly how health IT has affected work processes. An example of this would be the measurement of change in the time to complete patient documentation. If an article describes how the provider is required to respond to each pop-up reminder and that the time to finish documentation has increased on average, the article would be using a proximal measure of change in processing time related to the implementation of the application. In contrast, *distal measures* indicate that workflow has changed but do not describe directly how that change is related to health IT systems' effects on work processes. An example of this would be the ordering of tests. A research study may show only that the computerized decision support (CDS) system recommends ordering a type of test and that the test is ordered more often when the CDS system is in use. These two facts imply that workflow has changed, but the measure of test ordering rates does not describe how the work processes have changed. *Outcome measures* similarly imply that work processes are likely to have changed, but give no indication of how. For example, a study describing the implementation of a registry system for heart disease patients and measuring changes in the percent of those patients with hypertension would be using an outcome measure. A single study could contain a combination of proximal and distal process measures, and outcome measures, and many studies do.

In this literature review, we primarily focus on articles that use proximal measures of workflow. We argue that these proximal indicators show the direct impact of health IT interventions on workflow, while distal process and outcome measures leave important process changes unexamined, or "in a black box." Therefore, causality cannot be determined, the generalizability of results cannot be assessed and the mechanisms by which health IT makes an impact cannot be understood. Although we briefly discuss a small number of studies using distal measures and patient outcomes, we do so only to provide examples of some of the patterns we noticed in reviewing these types of articles.

Methods

To identify research studies for inclusion in the literature review, we performed a systematic literature search of 13 databases covering the fields of medicine, public health, health services research, social science, engineering, business, information services and library science. We searched abstracts and titles for the conjunction of three sets of search terms, specifically those related to ambulatory care, health IT and workflow or human factors methods. In all, 3,544 articles were found.

In an effort to include all relevant systematic literature reviews, we also searched PubMed® for review articles with one of the health IT terms in the title. We classified the articles by type of health IT and selected 30 for closer review by the entire team and the contract's AHRQ project officer. Twelve articles were selected for inclusion. We also included their references and all publications citing them, adding 1,479 articles in all.

Excluding duplicates, 4,470 articles were reviewed by a member of the research team. The inclusion criteria were that the article must be published in 1980 or later, written in English, peer-reviewed, focused on the implementation of health IT in an ambulatory care setting or the use of health IT to analyze workflow in an ambulatory setting, and describing proximal measures of work process change. Full-text versions of the selected articles were then reviewed by a human factors engineer.

Results

In the end, 192 relevant articles were identified in the literature review, 4,068 articles were deemed not relevant because they did not meet one of the inclusion criteria, and 64 articles using distal measures of workflow change were found to be useful as examples. The latter group are not included in the literature review, but are briefly summarized in this report. For the 192 relevant articles, findings on workflow changes related to health IT implementation and the use of health IT to analyze workflow have been summarized in a Microsoft® Office Access 2000 database. The data were transferred to a searchable Oracle® database that is included in the "research" section of the toolkit.

The most common study design types were randomized controlled trials (18 percent), pre-post design without a control group (15 percent), post-implementation analysis without a control group (35 percent) and systematic literature reviews (16 percent). By far, the most common care setting described in the articles was primary care (54 percent) or both primary and specialty care (20 percent). The majority of clinics described in these articles (61 percent) were affiliated with a medical center, HMO, the Veterans Administration or a national health care system outside of the United States. Only two of the articles described clinics that could be identified as independently run, though it is likely that some of the clinics with unknown affiliation status were also independent. Only 21 percent of the studies focus exclusively on small or medium-sized clinics. Many of the articles describe large clinics (38 percent) or both small/medium and large clinics (12 percent). Approximately one-third of the articles described only clinics located in urban areas (33 percent). An additional 22 percent of the articles described at least some practices located in rural areas. Clinics in suburban areas were less likely to be studied and are discussed in 14 percent of articles. The most common type of health IT is decision support systems, including electronic alerts and reminders (40 percent). To allow more detailed analysis of this category, it was further divided according to the goal of the system, including chronic disease management (22 percent), preventive care (14 percent), and medication prescribing (20 percent). Other common types of health IT applications are electronic health records (EHRs) and electronic medical records (EMRs, 23 percent), electronic prescribing (4 percent), telemedicine (19 percent), and informational resources for providers and patients (7 percent).

Syntheses

To facilitate a clear discussion of the effects of health IT implementation on workflow, we have emulated Shekelle et al.[10] in focusing on key topics of interest that can be addressed by the literature. In our case, we have written syntheses describing the workflow changes associated with specific types of health IT applications. Changes related to EHR/EMR implementation were found in the areas of interaction and communication between providers and patients, the work time of physicians and clinic staff, workload, access to information, legibility of records, ease of data extraction, and documentation. For decision support systems, we found effects on guideline adherence, length of consultations, communication between the provider and patient, providers' time, new tasks, team coordination, and access to information. The implementation of electronic prescribing systems was found to affect the efficiency of processes and processing time. Telemedicine implementations were described in the literature as having an impact on the time of providers and patients, collaboration, coordination, communication, role flexibility, and workload. The implementation of informational resource systems was found to affect the knowledge of providers and the reference information available to them. For each type of health IT applications, we also found changes related to acceptance and usability.

In the literature, we found that health IT had been used to analyze workflow in 54 studies. Most of these were evaluations of health IT usage or functioning, but some examined the time of clinic staff, physician adherence with decision support recommendations, coding accuracy, communication through electronic messaging, and the quality of documentation.

Conclusion

We conducted an evaluation of the peer-reviewed literature on workflow changes related to health IT implementation and the use of health IT as a tool to analyze workflow. Although we aimed to review as much of this literature on these topics as possible, we may have missed some articles. To identify a reasonable amount of literature to review, we selected three sets of search terms—on ambulatory care, health IT and workflow—and searched the conjunction of the three. As we learned in reading articles identified through a search of systematic literature reviews on health IT implementation, however, several authors discussed workflow changes without explicitly using any of our workflow search terms in the abstract or title. Such articles could have been missed by our search, even though we reviewed almost 4,500 articles.

In doing this review, we also gave careful consideration to what "workflow" is and focused only on proximal measures of workflow change, those that provide an explicit description of how the health IT has affected workflow. We compiled the findings into syntheses for each type of health IT, highlighting patterns of workflow changes that were found. We also briefly describe a selection of articles using distal and outcome measures of workflow to provide a sense of the issues that these articles address. Detailed information on each article in the literature review and its findings are described in the database on "research" in the toolkit. This information was also used to inform the toolkit's design and content.

Environmental Scan

Introduction

The purpose of the environmental scan was to learn what others were doing regarding health IT implementation and workflow in small and medium-sized ambulatory care practices. The objectives included: (1) identifying user stories and detailed data on workflow issues encountered in the development, implementation, adoption, and use of health IT; and (2) compiling a list of publicly available workflow design tools and methods applicable to ambulatory practice workflow analysis and redesign or related initiatives; including redesign efforts that use health IT as a tool.

Methods

The project team followed a three-step approach: (1) identification and review of key health care organizations and associations; (2) a broad, comprehensive Web-based search on small and medium-sized ambulatory care clinics, workflow, and health IT; and (3) a comprehensive literature search. More specifically, based on the expertise of project team members, feedback from AHRQ, and suggestions made by the project consultants, a list of organizations and associations was compiled. Information regarding the organizations and associations was gathered from various resources and if more information was necessary, additional follow-up was conducted. Secondly, a broad, comprehensive Web-based search on small and medium-sized ambulatory care clinics, workflow, and health IT was conducted using the literature search terms to perform focused and nonsystematic Web searches. A snowball technique was used as a Web site would often refer to relevant resources on another Web site. Resources involving a user story or tool were recorded in an EndNote® database and key information documented in Microsoft® Office Access 2000 databases. Thirdly, as part of the literature search a total of 13 academic research databases were searched. Both peer-reviewed and nonpeer-reviewed references containing user stories and tools relevant to the objectives of the environmental scan were recorded in the EndNote® database and key information documented. Relevant tools were also identified in a search of books in WorldCat using the same terms used in the literature search. Additional books were recommended by the research team, Technical Expert Panel (TEP), and consultants. The references were recorded in the EndNote® database and key information documented.

Results

A total of 87 organizations' and associations' publicly available materials were identified and reviewed. Workflow issues encountered were summarized into the following categories: tasks, time and cost, and other. For example, several organizations commented on the additional time required to complete new tasks after health IT implementation. Workflow guidance found in reviewing these organizations was also summarized. The categories of advice were infrastructure, stakeholders, vendor advice, training, tools for analysis, types of workflow, workflow analysis, workflow enhancement, and general. For example, one organization noted that small or rural practices may encounter challenges with broadband connectivity and the lack of access to skilled professionals who could assist in hardware selection and maintenance.
A list of useful Web links was compiled that included additional resources related to health IT implementation. The list includes links provided by associations such as the American Association of Family Physicians (AAFP), the American College of Physicians (ACP), the Institute for Healthcare Improvement (IHI) and the Medical Group Management Association (MGMA). These links are part of the toolkit.

We identified user stories that were included in the toolkit—published stories of workflow issues encountered before, during or after health IT implementation in small and medium-sized ambulatory care clinics. Through these user stories, toolkit users should be able to identify ambulatory clinics similar to themselves with the goal that they be able to anticipate workflow issues before, during or after health IT implementation. Summaries of these user stories are in the database that is part of the toolkit. The workflow results found in the user stories are categorized and summarized in Chapter 3. Tools for workflow analysis were also described in the user stories, as was the use of health IT as a tool to analyze workflow.
A list of tools was compiled, including instruments, methods, and strategies used to (1) collect information on, depict, and understand workflow, (2) inform workflow issues being addressed, and (3) recognize how the impact of implementation and use of health IT affects workflow. These tools were classified into the following categories: data collection, data display and organization, idea creation, problem solving, process improvement, process mapping, project planning and management, risk assessment, statistical tools, task analysis, usability, and health IT.

From this list, number of basic tools were selected based on their relative ease-of-use, value for accurately assessing and capturing workflow and the frequency with which they were reported in the user stories or literature review papers. Those chosen were check list, flowchart, interview, observation, risk assessment, usability, benchmarking, and health IT.

Conclusion

The environmental scan produced many user stories and tools relevant to workflow analysis and redesign for health IT implementation in ambulatory care practices. A unifying theme amongst all references is that practices must have a comprehensive understanding of how clinical and administrative work is performed in their environment and how these processes might change with the introduction of health IT. All relevant information from the environmental scan and literature review are synthesized and displayed in the toolkit.

Assessment of the State of the Field

Although our literature review unearthed a great deal of information on (1) the effects of health IT implementation on workflow and (2) the use of health IT to analyze workflow, the quality of the findings is weak for many reasons. Most of the articles we found were not focused directly on workflow, so the quality of evidence related to workflow change varied substantially. Workflow measures also include such a variety of topics that comparisons and generalizations are difficult to make. Even the definition of a specific type of health IT (such as electronic prescribing) varied across articles, making comparisons even more challenging.

The majority of studies described research completed in large clinics affiliated with academic medical centers, health maintenance organizations or national health systems outside the US. This greatly limits the generalizability of our findings for the small and medium-sized clinics that are the end users of the toolkit. Also, although a substantial minority of articles were randomized controlled trials (RCTs), most of the studies did not use a scientifically rigorous design, limiting inferences of causality. As we discuss in Chapter 4, however, many barriers make it difficult to conduct a RCT to study health IT. Finally, most of the literature did not include descriptions of the socio-technical context of health IT implementations and use, making it difficult to understand the role of potentially conflating or mediating factors such as training, technical support, and organizational culture. Thus, although our findings on workflow change and analysis are suggestive, intriguing, and sometimes consistent across many studies, more research is needed to draw firm conclusions about the relationship between health IT and workflow.

Conclusions

In conducting the literature review and environmental scan, we have gathered a great deal of information about the effects of health IT implementation on workflow and the use of health IT to analyze workflow. Awareness is growing of the need to analyze workflow in order to ensure successful health IT implementation and the potential for health IT be used in process improvement. Our sources of information included peer-reviewed literature, grey literature, organizations helping clinics to implement health IT, health IT vendors, and professional associations. We have discovered that some workflow changes associated with implementation seem to be nearly universal, such as the increased workload of physicians in clinics that have implemented an EHR. Others may be unique to the context of a particular clinic, such as a physician's lack of acceptance of a new health IT application. Unfortunately, most of the evidence that fills this report is anecdotal, insufficiently supported, or otherwise deficient in terms of scientific rigor.

Nevertheless, the information has been important in shaping the toolkit. We have gleaned useful facts about the end users for whom we are creating the toolkit, their likely needs and the best way to provide information so that it will be useful to them. We have also compiled a very comprehensive list of tools for workflow analysis, their advantages, disadvantages, and how to use them. From this list we have selected a small group of basic tools that would be most helpful to the end users; these are highlighted in the toolkit. We have discovered stories of health IT implementation and use for 37 clinics, stories that may provide other clinics with helpful foreknowledge about implementing health IT applications. The best of these are also highlighted in the toolkit.

The toolkit is the culmination of all the processes described in this report. It brings together information gathered from contacting organizations, reading countless Web sites, speaking with experts and reviewing thousands of journal articles. We hope it will prove useful to the small and medium-sized practices that are facing the daunting challenge of large-scale health IT implementations.

Chapter 1. Introduction

Health information technology (health IT) applications, which provide computerized clinical information to health care providers and/or patients, have been viewed as facilitating improved health care quality, enhanced patient safety and streamlined administration. The pace of health IT adoption in U.S. health care organizations will likely increase, owing in part to government incentive programs and pressures from purchasing groups and consumers.[1-8] Evaluations of the impact of health IT on quality and safety show mixed results, however. The main reasons seems to be a lack of integration of health IT into clinical workflow in a way that supports the cognitive work of the clinician and the workflows among organizations (e.g., between a clinic and community pharmacy), within a clinic and within a visit. It is clear that if health IT is to provide optimum performance, it must be designed to fit the specific context in which it will be used, specifically the type of practice and patients served. The purpose of this project is to develop a toolkit to help small and medium-sized ambulatory practices to assess their workflows and to successfully implement health IT. Small and medium-sized practices are likely to need the most help in analyzing their workflows as they typically do not have access to IT support and quality improvement resources.

In this project, our team of human factors engineers, physicians, and project staff has examined existing research related to the impacts of health IT on workflow in ambulatory settings and how health IT can be used to assess workflow in these settings. We have also identified currently available resources for workflow assessment in health care, as well as proven workflow analysis methods and instruments used in the fields of human factors and ergonomics, and industrial and systems engineering that could be applied in health care settings. We have synthesized the information gained into a toolkit that explains the importance of analyzing workflow when implementing and using health IT applications, summarizes commonly used methods for workflow assessment, explains the purpose of each method, describes how to implement the methods, explains the advantages and disadvantages of each approach, cites available resources for more in-depth information on each tool, and provides stories drawn from the literature and other sources that describe the experiences of small and medium-sized practices in implementing health IT.

One important issue for practices implementing electronic health records (EHRs) is the requirements for “meaningful use” that must be met to qualify for Medicare and Medicaid incentive payments. On July 13, 2010, the Secretary of the U.S. Department of Health and Human Services, Ms. Kathleen Sebelius, announced the final rule on meaningful use that will begin to apply in 2011. The final rule lists a total of 25 objectives, 20 of which must be met to qualify.[11] Fifteen of the objectives are required and the eligible EHR user must choose 5 of the remaining 10 objectives. The core elements and optional elements of meaningful use affect many aspects and types of workflow.

In the final rule published in the Federal Register, the Centers for Medicare & Medicaid Services (CMS) makes it clear that workflow redesign is critical for successful implementation and use of EHR: “… there is an expectation that the clinical workflow necessary to support the Stage 1 priority of data capture and sharing will be in place in order to effectively advance meaningful use of EHRs” (p. 44,337). Some of the required objectives include a minimum usage of the health IT application such as utilizing computerized provider order entry (CPOE) for “more than 30 percent of all unique patients with at least one medication in their medication list” (p. 44,567). Another necessitates that providers regularly “maintain an up-to-date problem list of current and active diagnosis" (p. 44,569), clearly affecting ways providers practice. Many affect communication between the provider, patient, and others including "clinical summaries provided to patients for more than 50 percent of all office visits within 3 business days" (p. 44,359).[11] Achieving these objectives will require workflow redesign for many clinics.

Workflow analysis is also essential for ensuring optimal use of other health IT applications, as well. Therefore, this toolkit will provide needed methods for analyzing and redesigning workflow that will be used by small and medium-sized practices before and during implementation of EHRs and other health IT systems, as well as after the implementation when they are aiming to achieve meaningful use of EHRs and optimal use of other health IT applications.

Project Background

This project aims to develop a practical and easy-to-use toolkit on workflow analysis and redesign that can be used by both small and large ambulatory care settings in the selection and implementation of health IT to support practice redesign.

AHRQ contracted with the University of Wisconsin-Madison to conduct the following activities related to health IT and workflow in ambulatory care settings:

- Assess existing research and evidence in the area of the impacts of health IT on workflow in ambulatory settings and how health IT can be used to analyze workflow in these settings,
- Identify currently available resources for workflow assessment in health care as well as proven workflow analysis methods and instruments used in the field of human factors and ergonomics that could be applied in health care settings, and
- Synthesize the information gained into a toolkit that explains the importance of analyzing workflow when implementing and using health IT applications, summarizes commonly used methods for workflow assessment, explains the purpose of each method, describes how to implement them, explains the advantages and disadvantages of each approach, cites available resources for more in-depth information on each tool, and provides "stories" drawn from the literature and other sources that describe the experiences of small and medium-sized practices in implementing health IT.

As part of the contract, a panel of experts in the field of health IT and workflow was created to provide feedback on the development of the toolkit. A list of the six experts who agreed to serve on the Technical Expert Panel (TEP) can be found in Appendix A.

Structure of this Report

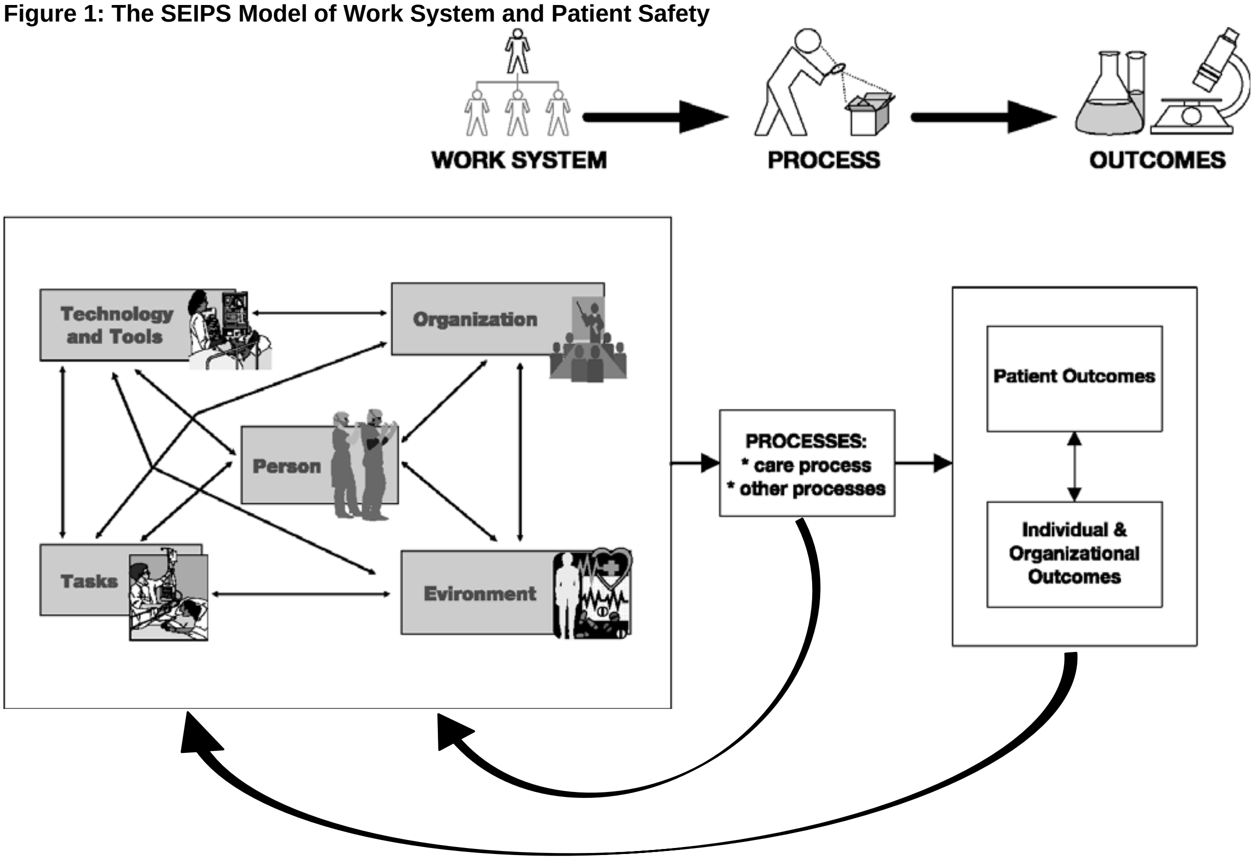
Chapter 2 describes the methods and findings of a review of the published academic literature. Chapter 3 contains the process and results of the environmental scan, including analysis of the grey literature and development of a list of tools for workflow analysis. Chapter 4 is an assessment of the state of the field using data from the literature review and environmental scan. It also describes gaps in knowledge that have been identified. Chapter 5 contains the conclusions of this report.

Chapter 2. Literature Review

Introduction

The literature review for this contract examines (1) how health IT for ambulatory health care delivery systems can impact workflow in small and medium-sized practices and (2) how health IT can be used to study workflow in these practices. Our discussion of these topics is grounded in the UW Systems Engineering Initiative for Patient Safety (SEIPS) Model of Work System and Patient Safety,[9] which has three main parts. The *work system* describes how a person at work performs a range of tasks using specific technology and tools, within a physical environment and within certain organizational conditions. The work system influences *processes*, or workflows, that often involve several workers and patients. These care processes create *outcomes* for the patient and the organization.[9]

Figure 1: The SEIPS Model of Work System and Patient Safety



Source: Carayon P, Hundt AS, Karsh B, et al. Work system design for patient safety: the SEIPS model. Qual Saf Health Care 2006;15(Suppl I): i50-i8.

In terms of the SEIPS model, our literature review can therefore be understood as examining how particular types of technology, specifically health IT applications, affect and can be used to analyze work processes that are products of the work system in small and medium-sized ambulatory health care organizations. In this context, workflow can include (1) patient workflow, (2) clinic provider or clinic staff workflow, (3) workflow between organizations, or (4) workflow taking place during or in-between clinic encounters.

Most research on health IT, however, is not focused directly on workflows within health care organizations. Typically, a study will aim to discover the effect of an application on adherence to care guidelines or on patient or organizational outcomes. For example, a researcher may examine whether the introduction of clinical decision support (CDS) affects the rate of screening for cancer in a specific type of patient. Such research clearly implies that process changes have occurred. If a reminder message “pops up” on the screen during a patient visit, the workflow of the provider is changed regardless of whether the provider responds to the reminder by counseling the patient about the need for cancer screening, whether the patient is screened or whether he has cancer. Studies vary substantially in how much information they provide on process changes, however.

In evaluating the literature, we have identified several types of measures that are used to assess the effects of health IT implementation on workflow, classified according to the amount of information each provides on changes in work processes. One such type is *proximal measures*, which describe how health IT has affected work processes. An example of this would be measurement of changes in the time to complete patient documentation. If an article describes how the provider is required to respond to each reminder and that the time to finish documentation has increased on average, the article would be using a proximal measure of change in processing time related to the implementation of the health IT. In contrast, *distal measures* indicate that workflow has changed but do not describe directly how that change is related to health IT systems’ effects on work processes. An example of this would be the ordering of tests. A research study may show only that the CDS recommends ordering a type of test and that the test is ordered more often. These two facts imply that workflow has changed, but the measure of test ordering rates does not describe how the work processes have changed. *Outcome measures* similarly imply that work processes are likely to have changed, but give no indication of how. For example, a study describing the implementation of a registry system for heart disease patients and measuring changes in the percent of those patients with hypertension would be using an outcome measure. A single study could contain a combination of proximal and distal process measures and outcome measures, and many studies do.

In Table 1 below, we describe the three types of measures related to workflow that were found in the literature and provide examples of each.

Table 1: Typology of workflow measures with examples

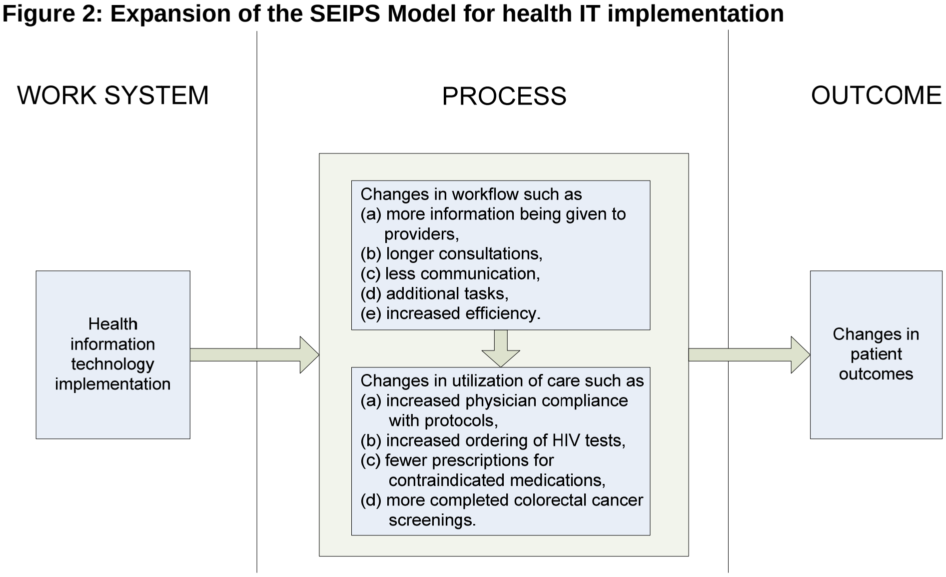
PROCESS		OUTCOME	
Proximal measures		**Outcome measures**	
Type of measure	Examples	Type of measure	Examples
Efficiency	Duplication of work	Patient health outcomes	Disease control Clinical test results Cost of care Rate of medication errors
Processing time	Patient waiting time Duration of consultation	Organizational outcomes	Profitability Quality measures
Communication	Number of questions asked by a patient Form of communication used between a nurse and provider		
Added tasks/ modified tasks	Increased data entry Coding of services by physicians		
Coordination	Change in triage procedures		
Information flow	Information provided to specialist		
Usability of health IT	Perceived ease of health IT use		
Acceptance of health IT	Willingness and eagerness of providers to use the health IT application		
Distal measures			
Patient health process rates	Ordering of tests Screening for disease Prescription of medications Performance of tests		

In this literature review, we primarily focus on articles that use proximal measures of workflow. We believe that these proximal indicators show the direct outcomes of health IT interventions, while distal process and outcome measures leave important process changes unexamined, or "in a black box." Therefore, causality cannot be determined, the generalizability of results cannot be assessed and the mechanisms by which health IT makes an impact cannot be understood. For example, a recent study showed that implementation of an electronic disease management system and provision of performance feedback to providers was associated with an improvement in control of diabetes symptoms for patients.[12] The control of diabetes symptoms is an outcome measure. Positive findings do not definitively support the hypothesis that electronic disease management systems improve diabetes control because process changes must have occurred that explain how the health IT use had this effect. In such a study, we do not know if the electronic system: (a) provided more clear indications to the clinicians of which patients were diabetics, (b) automatically sent education letters to all diabetics, (c) was used to provide data to a case manager who called all diabetic patients to talk about control, or (d) caused any other process changes to be made. Positive outcome results would be suggestive, but proximal measures of change are needed to understand workflow change. Similarly, a study of patient outcomes may describe the implementation of specific types of health IT functions that have the potential to change patient outcomes, but frequently do not measure if the functions were used. For example, Weber[13] describes the functions of a registry for diabetes patients that is integrated into an EHR and how the new system allows providers to more easily access diabetes data and trends. This study was not included in the literature review for this contract because it did not measure how workflow changed after new data on diabetes patients became available.

Thus, in this review of the literature we have focused our efforts on studies using proximal measures of workflow change related to health IT implementation in small and medium-sized practices and studies of the use of health IT to analyze workflow in these practices. Later in this chapter, we briefly discuss a small number of studies using distal process measures and patient outcomes but only to provide examples of some of the patterns we noticed in reviewing these types of articles. Another justification for focusing on proximal measures comes from our conversations with providers who are likely to be end users of the toolkit. In following up on request for information responses or environmental scan findings, some providers expressed concern about how workflow would change with health IT implementation. Specifically, they described worries about being required to change the way they practiced medicine, their interactions with patients, the time they had to spend in front of a computer and the flow of their work. All of these issues of concern are related to changes in proximal measures. As such, there appears to be strong face validity in focusing on studies of proximal changes.

One implication of our argument is an expansion of the SEIPS Model of Work System and Patient Safety. In the case of health IT implementation, such a model might look like this.

Figure 2: Expansion of the SEIPS Model for health IT implementation



Literature Search Process

Methods

To identify research studies for inclusion in the literature review, we performed a systematic literature search of 13 databases covering the fields of medicine, public health, health services research, social science, engineering, business, information services, and library science (see Table 2).

Table 2: List of databases searched in systematic literature review

	Name of Database
1	PubMed
2	Web of Knowledge
3	Cumulative Index to Nursing and Allied Health Literature (CINAHL)
4	Cochrane Central Library
5	Cochrane Healthcare Technology Assessment Library
6	PsycInfo
7	Engineering Village, including both Compendex and Inspec
8	Health and Safety Science Abstracts
9	ABI/Inform
10	Business Source Elite
11	Dissertations and Theses at CIC
12	Library, Information Science and Technology Abstracts (LISTA)
13	Human Factors and Ergonomics Society (HFES) journals in Ingenta

We searched abstracts and titles for the conjunction of three sets of search terms, specifically those related to ambulatory care, health IT and workflow or human factors methods. In order to focus on articles relevant for the toolkit's target audience, we defined ambulatory care as excluding hospital emergency departments, ambulatory surgery centers, nursing homes, dialysis centers, school health facilities, dentist offices, optometrists, chiropractors, alternative medicine providers, and care provided solely in the patient's home. We defined health IT as excluding medication bar-coding and the electronic medication administration record (eMAR). See Table 3 for the specific terms searched. For databases with a thesaurus of indexed keywords, synonymous terms from the thesaurus were added to the set of search terms.

Table 3: Search terms used in the literature review

Topic	Search terms
Ambulatory care	"ambulatory care" OR "clinic" OR "physician practice" OR "outpatient" OR "primary care" OR "family medicine" OR "general practice" OR "pediatric*" OR "women's health"
Health IT	"information technology" OR "CPOE" OR "Order entry" OR "decision support" OR "CDS" OR "CDS" OR "electronic health record" OR "EHR" OR "electronic medical record" OR "EMR" OR "e-prescribing" OR "eRx" OR ("computer" AND "reminder") OR ("electronic" AND "reminder") OR ("computer" AND "alert") OR ("electronic" AND "alert") OR "CPRS" OR "Computerized Patient Record System" OR "PACS" OR "Picture Archiving and Communication System" OR "computerized radiology" OR "digital imaging" OR "telemedicine" OR "disease registries"
Workflow or human factors methods	"workflow" OR "work flow" OR "process flow" OR "usability" OR "process mapping" OR "six sigma" OR "flow charting" OR "task analysis" OR "process analysis" OR "time study" OR "industrial engineering methods" OR "human factors methods" OR "role network analysis" OR "lean management" OR "job analysis" OR "work analysis" or "work measurement"

Inclusion criteria at this stage of the search were that articles must be published in 1980 or later and written in English. In all, 3,544 articles were found.

In an effort to include all relevant systematic literature reviews, we searched PubMed for review articles with one of the health IT terms in the title. Of the 803 articles found, we excluded 272 that were not published recently (in 2000 or later) or were not in English. We classified the remaining 531 review articles by type of health IT and selected 30 for closer review by the entire team and the AHRQ project officer. Twelve articles were selected and are listed in Appendix B. These articles, their references and all publications citing them were added to the list of potentially relevant articles, 1,479 in all.

Excluding duplicates, 4,470 articles were found in the literature search. The abstracts and, as needed, full text, of these articles were reviewed by a member of the research team. The inclusion criteria at this stage were the same as described above, as well as that the articles must be peer-reviewed, focus on the implementation of health IT in an ambulatory care setting or the use of health IT to analyze workflow in an ambulatory setting, and describe proximal measures of work process change. Full-text versions of the selected articles were then reviewed by a human factors engineer. Grey literature articles (not peer-reviewed) were excluded from the literature review but assessed for inclusion in the environmental scan. A total of 146 grey literature articles were added to the environmental scan database.

In the end, 192 relevant articles were identified in the literature review, 4,068 articles were deemed not relevant because they did not meet one of the inclusion criteria, and 64 articles using distal measures of workflow change were found to be useful as examples. The latter group are not included in the literature review, but are briefly summarized in this report. For the 192 relevant articles, findings on workflow changes related to health IT implementation and the use of health IT to analyze workflow have been summarized in a Microsoft® Office Access 2000 database. A searchable version of the database is included in the "research" section of the toolkit. The fields in this database are described in Table 4. Thirty of the relevant articles are systematic literature reviews. Their conclusions are summarized in the database, but the findings of the individual articles described within the systematic reviews are not summarized.

Table 4: Fields in the searchable database of literature review articles

Field	Description
Full Reference	
Abstract	
Objective of the study	
Type of study design	Randomized controlled trial (RCT) Pre-post design with intervention and control groups Pre-post design without a control group Post only design with intervention and control groups Post only design without a control group Systematic literature review Narrative Other design (such as a nationally representative survey)
Care setting	Primary care, specialty care, both types, unknown
Type of care setting	E.g., family practice, orthopedics, or dermatology
System affiliation	Affiliated with a larger health care organization (e.g., a medical center or an HMO), not affiliated, unknown
Size of clinic	Number of providers, number of staff and/or number of patient visits, as well as other text from the article describing practice size. These data were used to categorize the practice(s) described in the article as "small or medium-sized practices" with fewer than 25 providers; "large practices" with 25 or more providers; small/medium and large practices; unknown size; or not applicable (because no individual clinics are described)
Geography	Rural; suburban; urban; rural and urban; suburban and urban; rural, suburban and urban; or unknown
Study participants	Description of the participants whose workflow is being analyzed
Context: Other IT in place	Description of other health IT existing in the clinic, e.g., a practice management system or HER
Type of health IT	Type of health IT whose effects on workflow are being analyzed, e.g., a CDS system
Application name and vendor	Name of the health IT system whose effects are being analyzed and the application vendor
Functions	Description of the functions of the health IT being analyzed
Type of workflow being analyzed	Categories describing the workflow, e.g., communication, processing time, efficiency, or information flow

Field	Description
Data collection method	Method by which the workflow finding was assessed, e.g., a questionnaire, observation, interviews, or data extracted from the health IT system
Results of workflow assessment	Description of the change in workflow related to the implementation of health IT or found by using health IT to analyze workflow
Tools	Tools used to analyze workflow, e.g., flowcharts or usability testing
Health IT used as a tool?	Yes or no
Web site or link	Permanent Web address for a free full-text version of the article, if one is available

Description of Findings

Table 5 describes the characteristics of the 192 articles included in the literature review. The most common study design types were randomized controlled trials (18 percent), pre-post design without a control group (15 percent), post-implementation analysis without a control group (35 percent) and systematic literature reviews (16 percent). By far, the most common care setting described in the articles was primary care (54 percent) or both primary and specialty care (20 percent). The care setting could not be identified in 19 percent of the articles. The majority of clinics described in these articles (61 percent) were affiliated with a medical center, health maintenance organization (HMO), the Veterans Administration, or a national health care system outside of the United States. Only two of the articles described clinics that could be identified as independently run, though it is likely that some of the clinics with unknown affiliation status were also independent. Only 21 percent of the studies focus exclusively on small or medium-sized clinics. Many of the articles describe large clinics (38 percent) or both small/medium and large clinics (12 percent). In an additional 29 percent of the studies, individual clinics were not described (19 percent) or the size of the clinic is unknown (9 percent). Approximately one-third of the articles described only clinics located in urban areas (33 percent). An additional 22 percent of the articles described at least some practices located in rural areas. Clinics in suburban areas were less likely to be studied and are discussed in 14 percent of articles. Over one third of the articles (39 percent) do not provide information about the location of the clinics analyzed.

Table 5: Types of articles found in the literature review

	Number of articles	Percentages
Study Design		
Randomized Controlled Trial (RCT)	34	17.7%
Pre-Post with Control Group	8	4.2%
Pre-Post without Control Group	28	14.6%
Only Post with Control Group	15	7.8%
Only Post without Control Group	68	35.4%
Systematic Literature Review	30	15.6%
Narrative	5	2.6%
Other	4	2.1%
TOTAL	192	100.0%
Type of Care Setting		
Primary Care	104	54.2%
Specialty Care	14	7.3%
Both Primary and Specialty Care	38	19.8%
Unknown	36	18.7%
TOTAL	192	100.0%
System Affiliation of Clinic(s)		
Affiliated with Larger Health Care Organization	118	61.4%
Unaffiliated	2	1.0%

	Number of articles	Percentages
Unknown	72	37.5%
TOTAL	192	100.0%
Size of Clinic(s)		
Small or Medium (25 or fewer providers)	41	21.4%
Large (26 or more care providers)	73	38.0%
Both Small/Medium and Large	23	12.0%
Unknown	18	9.4%
Not Applicable	37	19.3%
TOTAL	192	100.00%
	Number of articles	Percentages
Location of Clinic(s)		
Rural Area	15	7.8%
Suburban Area	4	2.1%
Urban Area	64	33.3%
Rural and Urban Areas	13	6.8%
Suburban and Urban Areas	7	3.6%
Rural, Urban and Suburban Areas	15	7.8%
Unknown	74	38.5%
TOTAL	192	100.0%

Note: The definitions of some types of health IT have changed over time. When possible we used the type indicated by the study authors; otherwise, we classified the article using the definitions commonly accepted now.

Table 6 shows the types of health IT whose effect on workflow is analyzed in the literature review. The most common type is decision support systems, including electronic alerts and reminders (40 percent). To allow more detailed analysis of this category, it was further divided according to the goal of the system, including chronic disease management (22 percent), preventive care (14 percent), and medication prescribing (20 percent). Other common types of health IT are EHR and EMR (23 percent), electronic prescribing (4 percent), telemedicine (19 percent), and informational resources for providers and patients (7 percent).

Table 6: Types of health IT analyzed in the literature review

Type of Health Information Technology	Number of articles	Percentage of all articles
Electronic Health/Medical Records (EHR/EMR)	44	22.8%
Computerized Provider Order Entry (CPOE)	6	3.1%
Decision Support, including alerts and reminders	77	39.9%
Chronic Disease Management	17	22.1%
Preventive Care	11	14.3%
Prescribing	15	19.5%
All types	14	18.2%
Other	20	26.0%
Electronic Prescribing (e-Rx)	7	4.1%
Telemedicine	36	18.8%
Informational Resources	13	6.7%
Messaging and Data Sharing	8	4.1%
Digital Imaging	7	3.6%
Registries	3	1.6%
All Types	2	1.0%
Other	5	2.6%

Note: The percentages in this table do not add to 100 percent because several articles discuss more than one type of health IT.

Effects of Health IT Implementation on Workflow

To facilitate a clear discussion of the effects of health IT implementation on workflow, we have emulated Shekelle et al.[10] in focusing on key topics of interest that can be addressed by the literature found. In our case, we have written syntheses describing the workflow changes for specific types of health IT applications.

Electronic Records (EHR/EMR) and CPOE

This section summarizes the effects of implementing electronic records on practice workflow. Two main types of electronic records have been described in the literature, electronic health records (EHR) and electronic medical records (EMR). However, several other terms have also been used for electronic patient records (e.g., computerized patient records), and the terms EHR and EMR have not been used consistently. According to the current definition proposed by the Healthcare Information Management Systems Society (HIMSS)[14] and the National Alliance on Health Information Technology,[15] an EMR is used within a single care delivery organization. In contrast, an EHR "conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one health care organization" (p.15).[15] Although we would prefer to correctly categorize the systems described in these studies as EHRs and EMRs so that we can explore the effects of each type of health IT application on workflow, the articles do not usually provide enough information to permit this. We will therefore use the term EHR/EMR in this synthesis to describe all types of electronic records.

One key component of most electronic record systems is computerized provider order entry (CPOE). In the literature, the effects of implementing this health IT are frequently difficult to separate from the effects of EHR/EMR, as often the two are implemented at the same time and the applications are integrated. We will therefore discuss the effects of CPOE on workflow in this synthesis as well.

Some of the articles on EHR/EMR focused on a specific aspect of the application, such as documentation templates,[16] the use of computers in the exam room,[17-19] the electronic receipt and display of test results,[20] detection of adverse drug events,[21] or the availability of prescription information.[22] Other studies described comprehensive EHR/EMR systems that included electronic patient records, CPOE, and physician documentation.[23-30] Some of these comprehensive systems had additional features, such as decision support with reminders or alerts,[23, 24, 26-28, 31] electronic review of laboratory and radiology reports,[23-25, 30] electronic prescribing,[23, 24] documentation templates,[32] secure messaging,[16, 24, 27, 32, 33] registries,[27] personal health records accessible to patients,[24] integration with a practice management system,[32] and scheduling, billing, or financial data.[28, 30, 32, 33] Several studies examined the effect of implementing electronic records but did not describe the application well.[34-42] Other articles lacked details about the EHR/EMR because they were systematic literature reviews,[43-45] described a variety of systems,[46-50] or studied EHR/EMR applications in general instead of a particular system.[31, 51] Two articles described EHR/EMRs with limited functionalities, such as access to basic patient records.[52, 53] Of the few articles that were focused on CPOE, one stated that providers could use free text, or fill-in-the-blank templates in creating an order.[30] The others did not describe the CPOE system in detail.[54-57]

Commonly, workflow changes related to EHR/EMR implementation affected interaction, communication or the relationship between providers and patients. One study[19] described several patterns of provider interaction with the computer system in the examination room: (1) the provider mostly looked at the screen and used computer-guided questioning while entering information, (2) the provider alternated attention between the patient and the screen, and (3) the provider gave the majority of attention to the patient during the visit, rarely entered data in front of the patient and frequently turned the screen so patients could see the records being reviewed. Another study found that use of an EHR/EMR was associated with less conversation, particularly on psychosocial issues, but more data gathering, patient education and counseling.[18] Although some research found results to the contrary,[25, 36] most studies indicated that the presence of the computer terminal in the examination room was distracting for the provider and took attention away from the patient[42, 45, 52, 58] or that providers were concerned about the quality of communication[42] or preserving their relationship with patients while using the system.[33, 37, 45, 51] Some providers attempted to compensate for the distraction by reviewing patient records before the appointment,[33, 58] sharing information with patients during the appointment by turning the screen,[23] maintaining eye contact by turning away from the computer,[42] using a printout instead of the EHR/EMR during the appointment,[58] doing documentation after the patient had left,[33] or "using body language to show attention and empathy, [and] using humor to reduce tension" (p. 345).[42] One study found that physicians who were more proficient with computers were better able to communicate with patients while using a computer system.[42] Others reported that physicians sometimes preferred documenting while the patient was present because it improved the quality of patient records.[33, 54] In related research, providers using electronic records were found to be sensitive to subtle psychological cues, but in consultations about psychological issues, providers used the computer system less of the time relative to visits in which no psychological issues were discussed.[36] Patients were also concerned about the effects of computer use on their interactions with providers,[41] although one study found that implementation of the system did not affect patient satisfaction with patient-provider communication, even about their emotional concerns.[17]

Another common issue discussed in the literature is the effect of the health IT on the time of physicians and support staff. Several studies found time savings using features such as text templates,[33] the automatic transfer of billing data,[31] computer-printed prescriptions,[45, 49, 58] electronic prescription reordering,[33, 58] and the automatic transferring of information into referral letters, requisitions and forms.[33] One study noted that patients were satisfied with the heath IT system's effect on the overall timeliness of activities.[17] Other research described tasks requiring more time when electronic records were used, such as data entry[37] (especially for providers who were not computer literate[52]), and working with patient data that was divided between paper charts and electronic records.[39] Several studies noted that the patient spent more time in the examination room with the provider[29, 45, 52] or in the waiting room[34] after implementation of the electronic system, though two studies found the opposite effect, at least for some practices,[32, 53] and one found no significant change.[26] In several studies, the use of CPOE was found to involve duplication of efforts, as information was transferred from paper to electronic records and later printed,[54] or orders needed to be re-entered into a pharmacy system that was not integrated into the EHR/EMR.[56] A systematic review[57] found mixed results for the effect of CPOE on the time for physicians to complete orders, with some studies confirming physicians' belief that CPOE requires more time than paper ordering, but one study showing that CPOE was time-neutral. The same systematic review noted that certain CPOE features can reduce physicians' time burden, including order sets, remote access to the CPOE system, and easy access to reference materials and patient data.[57] One study found that physicians using the CPOE system “continued to perform certain tasks using paper-based methods even though the computer was automatically performing those tasks for them” (p. 367)[30] and that time costs declined as physicians grew more familiar with the system.[30]

A related issue is the effect of the EHR/EMR and CPOE implementation on workload, defined as the hours of work and amount of work performed in a day. Several studies reported that physicians[32, 33, 37, 44, 47, 54, 55] or all clinic staff[35] experienced a higher workload after the implementation of an EHR/EMR system. Another study stated that physicians spent more time than expected in using the EHR/EMR.[46] One article described the perception by physicians that they spent more time on documentation, scheduling, billing and other tasks after implementation, in part because documentation on a large number of screens was required for each patient visit.[37] Two studies referred to the shifting of administrative tasks from support staff to physicians[33, 45] as one reason why physicians spent more time using electronic records.

Changes in the access to information, legibility of records, and ease of data extraction are also key issues related to the implementation of EHR/EMR systems. Physicians appreciated greater access to information both on terminals in the clinic,[31, 33, 34, 58] and at locations outside of the clinic,[27, 31, 32, 58] such as the provider’s home or office. In one study, physicians mentioned the ease of finding a particular piece of information in the EHR/EMR,[42] although another article described how redundant information in electronic records made searches time consuming and ineffective.[33] Some features that providers found useful were the ability to prepare for appointments by examining the patient’s medical records,[58] rapid updating of problem and medication lists,[58] and access to features such as educational tools,[58] prescription information,[22, 58] and medication formularies.[58] Several studies mentioned that physicians were pleased by the legibility of electronic records.[30, 37, 42, 47, 49] Findings on data extraction were mixed. Three studies found data extraction from an EHR/EMR to be much easier than using paper records,[46, 48, 53] but one of these mentioned that extracting performance data from the EHR/EMR was resource-intensive and required the programming of queries.[46]

The implementation of EHR/EMR also had effects on documentation by physicians and other providers, particularly when templates were used to guide the provider through a consultation or to ensure complete documentation. One study of several practices described a variety of methods for documentation in the EMR, ranging from dictated notes that were transcribed and imported into the system to the use of diagnosis-specific templates with prompts.[47] Another described physicians who created their own templates for physical examinations or common problems and used them either for ease of documentation or as a checklist during the consultation.[42] One study found that physicians had slightly positive opinions on templates[16] and another showed that templates were more favored by pediatrics residents than internal medicine residents.[25] Several studies found that templates improved the ease[33] or the quality[16, 47, 49] of documentation, and improved indicators of the quality of care.[38] One study found that using templates, nurses were better able to handle tasks such as reviewing the need for preventive care activities, reconciling medications and documenting health services performed outside of the practice.[38] In another project, clinicians avoided structured data entry using templates and the quality of documentation consequently suffered.[28] One concern about the use of templates is unnecessary duplication of information that is stored elsewhere in the medical record.[16]

The implementation of EHR/EMR was also found to affect communication among the care team. One study found that communication using the EHR/EMR messaging system was "egalitarian" (p.143-4) and "center[ed] on the goal of the interaction, with the content and direction being determined by the nature of the expertise required and the caregiver who possesses it" (p. 142).[58] Another article stated that electronic messaging improved the "availability, timeliness and accuracy" (p. 119) of information, as well as increasing the quality of documentation and reducing the likelihood of errors.[47] However, a study on CPOE reported that communication between physicians and staff was disrupted by implementation, so that staff only became aware of new orders when they heard the hum of the printer.[54]

A great deal of research addressed the acceptance of EHR/EMRs and CPOE by providers, clinic staff and patients. Most providers agreed that EHR/EMR systems were useful,[21, 26, 29, 36, 42, 45, 58] that benefits outweighed disadvantages[25] and that using the system did not disrupt practice.[25, 52] Nurses and clerical workers also were found to prefer electronic records over paper.[50] However, one study described how physicians found the EHR/EMR to be less useful than they had expected prior to implementation,[37] and another discovered that providers who value a close relationship with patients felt less positively about electronic records.[51] Patients were found to accept EHR/EMR well,[45, 58] and approve of the way their provider used the system in the exam room.[17, 33] In contrast, the acceptance of CPOE was mixed. A systematic review[55] described five studies showing that users were satisfied with the system and found it usable and three studies reporting that satisfaction and perceived usability declined after implementation. Many issues were found to affect the usability of EHR/EMR. Users complained about poor navigation,[47] such as having to "click" too often or flip between screens.[20] One physician developed a "workaround" for these navigation issues that involved keeping multiple windows open, but this increased the likelihood of errors in ordering or documentation.[20] Physicians also complained when screens were too crowded or "busy."[20] Nurse practitioners in charge of a nurse-run clinic found that the EHR/EMR screens did not match their workflow, so they invested considerable time and resources in reworking the system.[23] Other usability problems were difficulties in identifying the correct diagnostic and procedure codes,[37] a documentation system that had a steep learning curve,[47] lab orders that disappeared from the system once the lab was drawn,[23] progress notes that were difficult to display,[33] and low-speed internet connections that resulted in data interruption and loss.[23] Research documented how the use of EHR/EMRs can create new errors,[57] such as typos,[42] selecting the wrong entry from a drop-down list,[42] opening the wrong patient's chart,[42] or entering information into the wrong patient's chart because two charts were open at the same time.[42, 56] Clinicians discovered the need to double-check their orders to avoid these errors.[42, 54]

Summary. In all, many articles were found that describe the impact of EHR/EMR and CPOE implementation on workflow. After implementation, positive changes were found on the access to information, legibility of records, ease of data extraction and ability to easily create high quality documentation, especially using templates. Both positive and negative effects were found on the time of physicians and support staff and communication among the care team. Negative or neutral effects were found on physician workload and the interaction, communication and relationships between providers and patients. EHR/EMR systems were well accepted, while acceptance of CPOE showed no consistent pattern in the literature. A variety of issues affected the usability of these systems including navigation, interface design, and the creation of new errors.

Clinical Decision Support

We found 75 articles describing the effects of clinical decision support (CDS) applications on workflow. The types of care addressed by these systems varied widely, including chronic disease management, depression screening, diagnosis support, the identification of potential adverse drug events, medication prescribing and preventive care. In analyzing the descriptions of these systems, we noticed that those sharing a goal (such as improving physician adherence to preventive care guidelines) tended to be similar. The focus of a CDS typically had a strong impact on system design and how the application was incorporated into clinical workflows. For example, chronic disease management CDS are often triggered by patient characteristics indicating how well the disease is being controlled, while preventive care CDS typically produce reminders aimed at the primary care physician of a patient meeting specific criteria and attending the clinic for another purpose. Medication prescribing CDS are triggered by the selection of specific medications by the prescribing physician, and diagnosis support systems are triggered by the selection of a template or the entry of data on a specific type of patient symptom. Appropriate measures of adherence to the systems consequently vary. We chose to focus on three types of CDS systems for which the largest number of articles were found: chronic disease management, preventive care, and medication prescribing. Summaries of articles describing the workflow effects of other types of CDS systems are included in the toolkit's research database, but the articles are not included in the syntheses below.

Chronic disease management. Seventeen studies were found describing workflow related to the implementation of CDS for chronic disease management, two of which were systematic literature reviews.[59, 60] The conditions addressed were hypertension,[61-63] diabetes,[60, 64-66] heart failure/disease,[60, 66-70] asthma,[68, 71-73] chronic obstructive pulmonary disease,[71, 73] declines in functional status,[74] mental illness,[60] and chronic pain.[59] The design of most CDS systems was similar. All of the described systems produced recommendations for the care of a specific patient based on guidelines. Most systems drew data from an EHR or other electronic records but some required data to be entered into the CDS.[69, 70, 72, 75] The latter tended to have low rates of use,[69, 75] and their acceptance was affected by the burden of additional data entry, as is discussed below. With two exceptions,[65, 70] all described CDS were involuntarily triggered by rules applied to the electronic data (passive design), rather than requiring the physician to engage the system.

The vast majority of studies examined whether CDS improved guideline adherence and thereby the quality of care. The workflow changes examined were often increases in desired clinician behavior. After implementation of the CDS, physicians were found to increase the frequency of ordering laboratory tests,[64-66] prescribing drugs in a recommended class,[63, 66, 67] performing physical examinations,[64, 65] scheduling patient visits,[71] measuring pulmonary function,[71] and other guideline adherance.[60] One study found that physicians less often prescribed medications that were not recommended.[71] The findings of three studies showed no improvement in guideline adherence after CDS implementation.[68, 72, 73] Three studies found that physicians more frequently documented information on the conditions addressed by the CDS,[60, 61, 74] and one found they documented information in a more structured way so that it could be used by the decision support system.[71] In one study, requiring physicians to document specific information led to them entering information about the nonoccurrence of unlikely events without verifying the information with the patient.[61] A systematic literature review described mixed findings for the effects of decision support on visit frequency and referral rates and generally positive effects on treatment adherence and screening/testing.[60]

Other workflow changes were of concern because they would make the CDS less desirable for the physicians to use. CDS was found in two studies to increase the average length of time the physician spent with each patient,[61, 72] although one study found no significant increase.[64] Three studies reported that physicians felt using the CDS disrupted their interactions with the patient,[59, 70, 75] and observational data in one study indicated that use of the system did impede communication between the patient and physician to some extent.[70] However, in the same study patients did not report "experiencing any disturbance because their [physician] was using the computer or the CDS" (p.49)[70] Other research showed that many patients saw the system as having no impact on their communication, and that some patients found it beneficial for communication.[59] Two studies found that physicians avoided disrupting patient-physician interactions by using the system after the patient had left the exam room.[70, 75] This workaround may be problematic because if the system is not used as intended, at the point of care, the decision support will not be appropriately triggered during the patient visit.[75]

Overall acceptance of the CDS systems was mixed. Several studies describe evidence suggesting that physicians found the systems useful[59, 62, 66, 70, 72, 75] and believed their use led to better quality of care.[66, 72, 75] Many studies reported practitioner use as an indicator of acceptance. For systems requiring initiation by the practitioner, results showed that some clinicians used the system very frequently and others never[65, 70] or rarely[75] used it. One of these studies found that the rates of use were explained by physicians' comfort with and liking of computers.[70] Only light and moderate users complained that the reminders took too much time to review and cut into their time with patients.[70, 75] For some passive systems, the generated recommendations were frequently bypassed by physicians who did not open and read them,[71] did not notice the reminders,[66] or immediately exited from the CDS.[68, 69, 73] According to one study, reasons for bypassing the recommendations included "time constraints, an overwhelming amount of other clinical information to process, insufficient time to document an intervention that was performed outside of the practice…, an intervention was potentially painful or dangerous to a patient…, or because the recommendations were not considered appropriate for a given patient" (p. 95).[64] In another study, the authors commented that patients could present with an acute problem unrelated to the CDS recommendations and "might not wish to discuss" (p. 6) the chronic conditions that had triggered the system.[68] Other research found that physicians had negative attitudes toward the systems because they were "oversimplified, … hamper[ed] physician autonomy, and were intended to decrease health care costs" (p. 972),[69, 73] or were "annoying" (p. 261).[67]

Preventive care services. Eleven studies were identified that described workflow changes related to the introduction of a CDS for preventive care services. These studies examined the effects of preventive care reminders on encouraging cancer screening,[76-81] vaccination,[77, 82] blood pressure screening,[83] weight reduction,[77] HIV screening,[84]or a variety of preventive care services.[85, 86] One article was a systematic literature review of the cancer screening studies.[80] Five of these studies compared the effect of the decision support on rates of testing, response, adherence or overall effectiveness,[76, 77, 79, 81, 84] relative to a prior system. Two studies compared CDS systems to determine the effectiveness of each.[78, 82] One study aimed to determine facilitators and barriers to using CDS systems effectively for preventive care in a clinical setting.[86]

In all of these studies, the reminders were aimed at physicians, but three studies also examined the effect of sending reminders to patients.[81, 82, 85] In only one study were the reminders generated by the CDS in real time.[84] The systems used in five of the studies printed out reminders prior to the patient visit.[76-78, 82, 83] Two systems displayed reminders repeatedly until the desired action was completed.[78, 82] Only one system[76] required physicians to respond to the reminder by documenting why a preventive service was not provided. Also, in one study, physician managers were provided with feedback about the rates of screening in their group.[84] Three of the studies specifically stated that the CDS was integrated into an EHR/EMR system or analyzed data from electronic patient records in order to generate reminders.[76, 77, 86] Four studies described the set of rules or logic used to generate clinical reminders.[76, 77, 79, 86]

The largest number of workflow changes was related to providers' responses to the CDS reminders. Eight of the 11 studies discussed this topic,[76-80, 82, 83, 85] with 3 reporting the rates of test completion.[77, 82, 83] Three studies also reported outcomes that showed the decision support system had no impact.[76, 78, 85] One of these studies theorized that the lack of improvement was due to the complex nature of the test, rather than simply an ineffective reminder.[76] In another study, the results showed that the rate of patient screening was unaffected by whether their provider received an reminder,[78] and the third study saw the rate of preventive services discussions decrease post-implementation.[85] Three studies examining adherence found that rates for many measures improved as a result of the CDS,[76, 79, 85] especially when providers are required to document a response to each clinical reminder.[76] Also, study saw improved knowledge and a reduction in the difficulty of decisionmaking as a result of the reminders viewed by providers,[80] though this was accompanied by only a modest improvement in screening rates. Another study found improvements in documentation, specifically higher adherence to recording corrections and deletions to the appropriate area of a preventive care sheet within the electronic database—14 percent for the intervention group versus 1 percent for the control group.[76]

Other workflow changes were related to new tasks and team coordination. Two studies described how CDS systems resulted in new tasks being added to workflows.[81, 86] In the first study, clinic staff became responsible for all the data entry required for the system to work reliably.[81] In the second study, a workaround was created so that nurses were not required to spend additional time using the CDS during patient intake. Instead, a document with all the patient's reminders was printed during check-in, and the nurses recorded information on this paper printout during intake. The printout then traveled with the patient to the provider and back to the nurses, who later recorded the information in the EHR/EMR and "satisfied" the reminders.[86] Effects related to coordination included the fact that team coordination at one research site helped to catalyze the increase in screening rates related to implementation.[81] However, another study found that a lack of defined roles in the care team resulted in a general confusion about who was responsible for satisfying reminders.[86]

Usability issues were identified in 6 of the 11 studies.[76, 77, 80, 84-86] Of these six studies, three cited inappropriate alerts as a significant usability issue—providers received either false-positives or alerts that were not clinically relevant for the situation.[76, 77, 86] Customization was an issue in two of the studies.[84, 86] A primary complaint was a lack of response options to appropriately resolve a computerized reminder.[86] A slow, inefficient system was also found to be a problem in two studies.[77, 86] Problems ranged from a lack of information and delayed results[77] to a system which was both inefficient and time-consuming to use.[86] Clarity was also a key element in usability—one study described how a lack of clarity was a detriment to providers' ability to counsel patients,[84] and a second study demonstrated that a system providing clear and understandable messages simplified the patient counseling process.[85] Other usability issues mentioned include the helpfulness of having automated reminders,[80] problems with alerts that could not be resolved,[86] and confusion resulting from a poorly conceived user interface.[84] Five studies discussed acceptance of the CDS system.[79, 81, 83, 85, 86] Three reported results on the use of systems that were not triggered automatically.[81, 85, 86] These studies suggested that many providers were choosing to use the software—one reported an average system usage on 59 percent of the days of the study's duration.[81] Another study noted that 30 percent of providers reported frequent use of the system, while another 48 percent said they used the system "sometimes."[85] One study observed that only 6 of 55 study participants did not use the system at all.[86] Two studies reported issues related to a lack of acceptance.[79, 86] Participants either did not view the computerized reminders as an important work task,[86] or the system was initially accepted, but over time the use and intent to use the system decreased.[79]

Medication prescribing. Sixteen studies were identified that described workflow related to the introduction of a CDS for medication prescribing. Of these studies, three were systematic literature reviews.[87-89] Three studies aimed to determine the clinical impact of implementation,[90-92] while six others examined the benefits or barriers to use and adoption of the new system.[50, 87, 93-96] Three additional studies examined changes in the prescribing habits of providers in response to the CDS.[97-99]

Common functions of the systems analyzed in these studies included some form of alerts for contraindications related to allergies, drug interactions, dosing or pregnancy[87, 90, 93, 95, 96, 99] or similar safety checking involving the ordered drug and active medication orders. In four studies,[88, 90, 91, 96] the systems linked to or analyzed the patient health record, either to find active medication orders or to retrieve other patient information for the alerts. One study examined a system that used both paper-based tools and a CDS application,[100] and another featured a system with a drug-ordering pick-list.[92] A systematic literature review[88] reported that most "successful" CDS systems had the following characteristics: they provided a recommendation rather than just an assessment, they justified their recommendations by providing research evidence, and they used data standards that support integration with electronic patient records.

Twelve of the sixteen studies contained results pertaining to user response to alerts.[87-93, 96-100] Some of the topics included rates of alert acceptance,[90, 93, 99] overrides,[93, 96] and rates of reading educational information included in the alert.[92] Eight of the studies discussed the alerts' effectiveness.[87, 89, 91-93, 97, 98, 100] One of these studies saw a decrease in inappropriate prescriptions, as well as an increase in the discontinuation of prescriptions that could cause drug interactions.[91] Another found a large decrease in inappropriate antimicrobial use.[100] One study showed that physicians using the CDS more frequently ordered inexpensive generic medications in lieu of brand name alternatives.[92] Some sites noticed that CDS use was associated with positive changes in prescribing and dosing practices,[87, 97] as well as in the process of care, including medication timing and rates of sub-therapeutic dosing.[89] Another study found that after CDS implementation, serious dosing errors decreased by 55 percent.[93]

Several studies had workflow results involving communication and coordination. Improvements in communication between the physician and pharmacy were found. One study observed a decrease in queries from pharmacists about prescriptions,[94] and another study described how computerized messages facilitated discussions between pharmacists and physicians, which resulted in an improvement in the overall quality of care.[99] Coordination was affected by the CDS in one study that described a lack of clarity regarding who is responsible for making changes to prescriptions in response to an alert: physicians were uncomfortable changing a prescription that was written by another provider.[91]

The prescribing CDS systems also affected workflow in other ways.[50, 87, 94, 101] Two articles discussed clinicians' improved access to current medical information,[50, 94] with one of these studies noting an improvement in documentation due to the implementation of the CDS.[94] Others mentioned the helpfulness of dosing suggestions made in real time,[87] and time savings related to using a computerized system for prescription refills.[94]

Nine of the sixteen studies discussed the effect of a system's usability on workflow.[87, 90-93, 95, 96, 100, 101] One common issue was the relevance of alerts that were displayed.[90, 96, 101] One study[101] found that when using a system that does not grade severity of alerts, providers were least likely to override the alert without reading it, because they feared missing an important alert. Another study found that frequent and irrelevant alerts were distracting and disruptive to workflow.[93] Two studies cited a lack of clarity as being problematic,[87, 93] and one of these explained that problems arose when severe drug-drug interactions were displayed with several other alerts, making it difficult to discern which alerts were serious and required the most attention.[93] Three studies discussed whether the system lived up to users' expectations.[90, 93, 95] In 2 of these studies, the system failed to do so in certain areas—specifically a lack of valid override reasons[90] and inconsistent drug-allergy checking.[93] Ease-of-use was mentioned in two studies,[92, 93] with limited flexibility and customization noted as an issue in one of them.[93] Other topics that were mentioned included unstable software and hardware,[91] the value of an automated alerting system,[87] and issues with manual entry and operation of the system.[87, 100]

Six of the sixteen studies described results relating to acceptance.[89, 90, 92, 93, 95, 101] In one study, 56.2 percent of end users reported that CDS alerts changed the provider's initial decision "sometimes," 75.5 percent of end users felt the system provided new information "frequently/very frequently," 24.2 percent of users agreed that the CDS provided irrelevant information "never/rarely," 49.6 percent of users felt the system caused annoyance "never/rarely," and 88.1 percent of users felt the system drew attention to significant interactions.[101] Results from other studies found that the system enhanced "enjoyment of the practice of medicine" (p. 714)[95] and noted that acceptance increased as the number of interruptions from the system decreased.[90, 93]

Summary. Several patterns of workflow effects can be found in the syntheses on CDS systems. Although these syntheses are focused on CDS for chronic disease management, preventive care and medication prescribing, these patterns are likely to hold for most types of CDS. Many studies found that CDS systems improved the rates of desirable physician behavior, but not all. Several studies found no effect of CDS implementation, in some cases because providers routinely ignored the reminders. One common usability issue is the frequency of irrelevant alerts, which were disruptive of clinical workflow. Another problem was the clarity of alerts, either because confusing alerts were ineffective or because too many alerts made important ones difficult to identify. These usability issues affected acceptance of this type of health IT application. Some studies showed that physicians had negative views of the CDS systems and preferred not to use them, while others showed that physicians appreciated the information provided and used the system frequently.

Electronic Prescribing

A total of seven studies were identified describing workflow related to the introduction of an e-prescribing system into clinical practice, although it is important to note that the definition of electronic prescribing has changed over time. Early definitions included both stand-alone systems and those capable of electronically transmitting prescription data.[102] More recently, the

Centers for Medicare & Medicaid Services (CMS) have created a definition focused on electronic transmission of prescriptions.[103] We found that aside from one study which covered multiple clinical sites and did not describe the functions of the application,[49] three of the studies describe health IT applications fitting the CMS definition[104-106]and three did not.[107-109] A number of the systems printed or faxed prescriptions for patients,[104, 105, 107] had some form of formulary or medication list-related functionality,[105-107, 109] utilized features to speed up the ordering process,[105, 107] and provided drug information to the system users.[106, 109] Other less common features included weight-based pediatric dosing,[107] free-text entry with required fields,[107] and the display of other active medication orders.[105]

The existence of another IT system used in conjunction with the e-prescribing system was mentioned in four of the seven studies.[104, 105, 107, 108] These systems included EHRs[105, 107] and computerized practice management systems.[104, 108] In at least one of these studies,[107] the EHR communicated with the e-prescribing system, as information entered in one system could update the other.

Three[106, 107, 109] of the seven studies compared the e-prescribing system to a pre-existing noncomputerized prescribing system. Of the remaining four studies, two discussed implementation of e-prescribing systems[49, 104] and the remaining two described the effect of the health IT on work patterns of pharmacists and physicians[105] and the advantages and disadvantages of introducing an e-prescribing system into an office setting.[108]

All seven of the studies examined the effect of e-prescribing on efficiency. All studies except one[107] reported an improvement in overall efficiency. The study that did not report an improvement had a neutral result—"e-prescribing did not greatly disrupt prescriber or staff workflow" (p. 727).[107] Several of the studies were concerned about the effect on clinic staff;[49, 104, 105, 107-109] however, one study that investigated the effect of efficiency on patients found that the e-prescribing system saved patients time because it reduced the number of repeat trips to the pharmacy.[108]

Usability of the e-prescribing systems was an important area of evaluation, mentioned in four studies.[49, 104-106, 108] All four articles cited problems with the system's usability and explained the effects that these problems had on workflow. Providers at one site[104] did not like the fact that they could not look up drugs by brand name. Another study[49] noted that numerous and irrelevant warnings triggered within their e-prescribing system caused physicians to begin to ignore any warnings they saw. A third study[105] noted that a change in the format in which prescriptions could be entered made drug ordering easier for physicians, but caused increased problems downstream because pharmacists needed to edit more orders. The fourth study[108] cited more than one instance of the system being regarded as "cumbersome," which led to prescriptions being entered only when the facility was fully staffed. Many orders were still phoned in and hand-written.

The effect of e-prescribing on processing time was also evaluated in three studies.[105, 107, 108] The first reported improvements in processing time for pharmacy staff, but increased time spent on computer-based tasks for nurses and also increased time spent on miscellaneous tasks for nurses and medical assistants.[107] Processing time increased for pharmacists in the second study[105] because they had to spend increased time interpreting and editing physicians' orders. The time these pharmacists spent filling prescriptions decreased by 34 percent because they were spending more time troubleshooting incoming orders. The third[108] study showed a time savings related to decreases in the number of phone calls from pharmacies to the clinics because some problems with a prescription were flagged by the system and corrected before the prescription was sent.

However, the study also showed that patients had to wait 15-20 minutes for their prescriptions to be transferred from the clinic to the pharmacy.

Three studies[106, 108, 109] had results relating to the acceptance of e-prescribing. One study[109] found acceptance in the patient population—they believed that implementation of the e-prescribing system generally improved their care and the quality of work of their providers. In another study,[106] office managers expressed the opinion that e-prescribing made prescription and refill request completions easier to accomplish. In another site,[108] however, the e-prescribing system was only used for patients with multiple prescriptions, and the staff were reluctant to use the application without a firm commitment from physicians.

Summary. In all, the implementation of e-prescribing systems was found to have a positive or neutral effect on clinic efficiency, but no consistent pattern was found for the effect on processing time, especially in pharmacies. Usability issues with these applications included ineffective search functions, irrelevant warnings, and a simplification of the ordering process that led to more corrections being required of pharmacists. One system was cumbersome, leading to low acceptance and use by clinic staff; otherwise, these applications were well accepted by both patients and staff.

Telemedicine

The literature search on health IT implementation and workflow resulted in 40 articles about telemedicine. The next section briefly defines telemedicine and describes its common forms.

Definitions. Telemedicine is the use of information and telecommunications technology applications to transfer medical information for the purposes of diagnosis, therapy and education.[110] As defined by Norris,[111] three types of telemedicine applications were found in the literature review:

- Tele-consultation;
- Tele-education; and
- Tele-monitoring.

The most frequent type of telemedical procedure, *tele-consultation*, is used to support clinical decisionmaking by allowing caregivers, or the patient and one or more caregivers, to communicate over long distances either in real-time or using a store-and-forward method. *Tele-consultation* services are now used mostly to connect remote areas to urban centers. For example, in the numerous studies on tele-dermatology,[112-118] instead of referring patients to specialists, pictures of the affected area are taken by the primary care physician and then sent electronically to the specialist. If needed, a tele-conference consult can be conducted as well, to take the patients' (dermatologic) history and discuss the case with the patient and primary care physician. *Tele-education* includes academic courses or clinical education via the Internet and accessing medical online databases such as PubMed®. An example of *tele-education* is the study by Chan et al.,[119] in which pediatric patients with persistent asthma were provided with home computers and Internet access and were monitored bi-weekly over the Internet. Part of the sample (experimental group) received their asthma education via the Internet instead of receiving face-to-face education like the control group. Results show that there were no differences between the two groups for a number of outcomes.

Tele-monitoring is the use of telecommunications links to gather routine or repeated data on a patient's condition.[111] The purpose of *tele-monitoring* is to become aware of the need for adjustments in the patient's treatment. For example, blood glucose measurements of diabetes patients are automatically transferred via a modem[120, 121] or the internet[122] to a clinic. The physician at the receiving end is automatically notified about the receipt of data, examines the data and, if necessary, modifies the therapeutic protocol.

A more recent development is *tele-homecare*, which is a combination of *tele-monitoring* and *tele-consultation*. Patients are monitored electronically, and the data is sent to the clinician. The patient can also directly contact his or her physician using interactive audio/video systems.[123] Another variant is that instead of the physician visiting the patient at home, a specially trained community nurse visits the patient and reports to the physician.[124]

Most of the 40 studies found in this literature review were designed to evaluate *tele-consultation* or *tele-monitoring* applications. Some of the studies did include a *tele-education* component.

Effects on workflow. Among the results of the literature search, there were five systematic literature reviews. Three reviews focused on the impact of telemedicine applications on workflow. Curell et al.[125] concluded that the implementation of telemedicine can have a major impact on the organization of health care services and service delivery and administration, but these factors have been largely ignored in studies on telemedicine published between 1966 and 1999.[125] Roine et al.[126] examined a similar literature (published from 1966 to 2000) and included pilot projects and short-term outcomes in their review. They found evidence for the effect of telemedicine implementation on time-related consequences of health care services and on organizational issues. Jarvis-Selinger et al.[127] wrote a focused literature review on the impact of video-conferencing (VC) on clinical workflow practices and inter-professional collaboration. Results of the review showed that referring providers were positive about the potential to reduce unnecessary patient transfers and maintain care within the home community. They also found consequences of VC implementation on clinical workflow. For example, VC has an impact on coordination between health care providers, creating temporal and logistical challenges. However, VC implementation also can create a new context for team-based management, enabling team members to better communicate, and can result in more effective case management and decreased treatment time for patients. Another review with implications for workflow was Hakansson and Gavelin's survey of the telemedicine literature on cost effectiveness.[128] They concluded that telemedicine has had little impact on the medical practice, structure and organization of health care.

Only two studies other than these systematic literature reviews were focused on the effect of telemedicine implementation on workflow. MacFarlane et al.[129] examined role flexibility among telemedicine service providers and found that employees using telemedicine in primary care services act flexibly on a daily basis in order to ensure smooth operation of the systems. Aas[130] found that in four telemedicine services (tele-dermatology, tele-otolaryngology, tele-psychiatry, and a tele-pathology frozen-section service), implementation did not produce large changes in the distribution of tasks. He also found that implementation led primary care staff to do more patient care work, because learning effects over time allowed primary care physicians to treat some patients without referral to a specialist. As a consequence, telemedicine required more work for primary care practices than conventional referrals.[130]

Other studies mentioned the consequences of implementing telemedicine applications on workflow. For example, several studies examine *clinical efficiency and productivity*. In a randomized controlled trial comparing real-time tele-dermatology consultations to face-to-face appointments, Oakley et al.[118] found that the proportion of patients in tele-dermatology group (N=109) followed up by the dermatologist was almost the same (24 percent) as after a conventional appointment (26 percent) and for similar reasons. A study by Kruger et al.[121] examined whether modem transmission of blood glucose data by patients with gestational diabetes could provide faster communication of results, increased workflow efficiency, and equivalent accuracy of data. Results of the study showed no significant differences in consultation time, clinic workflow efficiency, or accuracy of data between the modem group and the control group who visited the clinic. Both patients and providers were very satisfied with the blood glucose meter and modem. Whited et al.[115] examined the effect of a tele-dermatology system and found that the time to evaluation and treatment for patients in the experimental group was significantly shorter than for patients in the control group (median 41 days vs. 127 days). Furthermore, 19 percent of patients in the experimental group avoided a visit to the dermatology clinic for consultation. In another study that examined the number of clinic visits, Miyasaka et al.[131] examined the clinical impact of a home digital video system for pediatric patients receiving long-term mechanical ventilation at home. The videophones allowed the transmission of clinically acceptable levels of chest wall movement, ventilator movement, chest radiographs, echocardiography, fiber-bronchoscopy images, and the emotional expression of patients and family members. Results of the study show that there were large reductions in number of house calls by physicians, unscheduled hospital visits, and hospital admission days after implementation of the system. Woods et al.[132] examined the impact of the implementation of three telemedicine clinics on the treatment of patients with sickle cell disease. Because this disease requires a chronic disease medical management approach, including close monitoring of medication adherence, blood testing, and early detection of disease-related and other medical complications, patients in rural areas that have limited access to health care resources need special attention. Results of the study showed that by using telemedicine, the productivity of the sickle cell clinic increased from 1,413 to 1,889 encounters in a year, with an increase in rural outreach activity from 271 to 745 encounters a year.

Several studies examined the impact of telemedicine on *consultation time* from the perspective of the provider or patient. All studies compared the length of tele-dermatology consultations to face-to-face consultations. Nordal et al.[117] found that on average, the duration of tele-dermatology consultations was slightly shorter (women (N=58): 9.6 minutes vs. 10.5 minutes for in-person consultations; men (N=55): 9.3 minutes vs. 9.8 minutes, no significance mentioned in article). However, the results of a laboratory study by Berghout et al.[113] showed that tele-dermatology consultations were longer on average by at least 3.5 minutes. Oakley et al.[118] found that patients in the telemedicine group spent significantly less time per appointment, including travel time (51 minutes compared with 4.3 hours for those with conventional appointments at a hospital clinic).

Other studies examined whether telemedicine implementation had an effect on the *distribution of clinical tasks*. Chase et al.[120] studied the modem transmission of glucose values and found that most modem transmission data were handled by nurses instead of physicians. However, as was mentioned above, Aas [130] showed that telemedicine does not produce large changes in the distribution of tasks between general practitioners and specialists, apart from tele-dermatology, where staff in the primary care sector undertake more patient care. Jaatinen et al.[133] examined whether the implementation of tele-consultation reduced the number of referrals to specialists and found that in more than half of the tele-consultation cases, the responsibility for treatment was maintained in primary care, without any visit to the hospital specialist being required.

Several studies examined the impact of telemedicine on the *workload* of physicians. In analyzing the effects of tele-consultation in the treatment of sickle cell disease in rural areas, Woods et al.[132] found that dramatic increases in the productivity of the sickle cell clinic (described above) only required the addition of a single physician assistant. MacFarlane et al.[129] examined role flexibility among telemedicine providers and found that employees took responsibility for new tasks or duties *in addition* to their existing ones; those tasks were often outside their professional roles, such as administrative duties.[129] A study of tele-consultation in otolaryngology found that primary care physicians are required to learn how to operate the equipment but that once proficiency has been achieved, the system will allow more efficient use of the specialist's time.[134]

Other studies examined a range of effects of telemedicine on workflow. Results show that accuracy of the measured data/diagnosis in telemedicine is often equal to or even better than in clinic visits.[112, 113, 116, 117, 121, 124] Results also show that quality of communication between patients and physicians and/or between primary care physicians and specialists generally increases as a result of telemedicine implementation;[117, 133, 135-139] that patient adherence to treatment increases;[132, 140] that the number of referrals and clinic visits is usually reduced;[114, 115, 132, 133, 141, 142] that the number of house calls by physicians is reduced;[124, 131] and that travelling time by both physicians[124] and patients[118, 137, 138, 142, 143] is significantly reduced. Overall, both patients[116, 117, 119, 120, 132, 133, 136, 140, 141, 144-147] and physicians[140] are satisfied with telemedicine, and there are few problems with usability.[122, 123, 142, 146, 148, 149] See Table 7 for details.

Table 7: Indirect effects of telemedicine applications on workflow

No.	Effect
1	Accuracy of measured data/diagnosis[112, 113, 116, 117, 121, 124]
2	Communication between patient and physician[117, 135-139]
3	Communication between primary care physician and specialist[133, 135]
4	Patient adherence to treatment [132, 140]
5	Number of clinic visits[115, 132, 142]
6	Number of house calls by physicians[124, 131]
7	Number of referrals[114, 133, 141]
8	Patient satisfaction[116, 117, 119, 120, 132, 133, 136, 140, 141, 144-147]
9	Physician satisfaction[140]
10	Traveling time for (visiting) physician[124]
11	Traveling time for patient[118, 137, 138, 142, 143]
12	Perceived usability by patients[122, 123, 146, 149]
13	Perceived usability by physicians[142, 148]

Summary. In conclusion, Currrell et al.[125] stated in 2000 that the implementation of telemedicine can have a major impact on the organization of health care services and service delivery and administration, but that these factors have been largely ignored in studies of telemedicine. Now, 10 years later, the situation has not changed drastically. Results of this literature review show that relatively few studies have *focused* on workflow. Most of the studies focused on cost-benefit assessment of telemedicine and clinical efficiency. With regard to the effects of telemedicine on workflow, most of the studies show that work activities are transferred from specialists to physicians, support staff, and technicians in primary care settings. Most of the physicians, both specialists and primary care providers, are satisfied with telemedicine implementations. Results of many studies show that the clinical effectiveness of telemedicine is most of the time equal to or better than traditional care, although there are also several studies that report lower effectiveness. For most patients, telemedicine means less travel time, and less lost work time. Perhaps consequently, patients are satisfied with the telemedicine interventions.

Thus, telemedicine implementation could potentially have a large impact on workflow, but based on the results of this literature review, we can only conclude that telemedicine has not been implemented on a large scale, and therefore has had relatively limited impact.

Informational Resources

A total of 12 studies were identified that describe workflow changes related to the implementation of an informational resource application. One of these studies was a systematic literature review.[150] Five studies looked into the effects of introducing an informational resource program,[150-154] and 3 discussed implementation strategies and results.[155-157]

The health IT applications in this category were diverse both in their structure and in their purpose. Two of the systems were either entirely Web-based or had some Web-based components.[155, 156] The others were stand-alone applications available on a desktop computer[151, 152, 154, 158-161] or hand-held device.[153] Two systems were information retrieval applications for clinicians who needed the answer to a specific question—one searched a database of evidence based medicine located on a hand-held device,[153] and the other sent a request to a research librarian, who created a written synthesis of the appropriate literature and sent it to the clinician via e-mail.[157] Three systems provided a variety of information to physicians for browsing or searching. One provided a structured “knowledge management system” that contained links to multimedia files,[161] one was a Web page providing links to online health resources such as MedlinePlus,[156] and one was a comprehensive Web site containing care guidelines, drug formularies, administrative procedures and other information.[155] Other systems aimed at physicians included one that calculated the risk of coronary heart disease for each patient,[151] one using a free-text search to provide a list of suggested terms for coding,[158] and one aimed to educate clinicians about cultural differences in ethnic elderly adults.[160] Three systems were intended for use by patients: one aimed to increase their interest in colorectal cancer screening by using video and narration to provide information about the tests,[159] another provided explanatory information to patients about their diagnosis and treatment to patients with migraines,[152] and a third asked patients questions about health behaviors and provided feedback about how changing the behaviors would improve related symptoms they experienced.[154]

Three studies found that the application enhanced the knowledge of its users in a meaningful way.[152, 153, 159] A systematic literature review[150] described how clinical information retrieval applications had improved decisionmaking, the use of clinical evidence, and overall patient care. It also mentioned that the applications update physicians’ knowledge and help them to remember forgotten information.[150] One study found that electronic resources were used despite the time constraints of heavy patient loads.[156] Patients receiving educational information through the system in one study felt that it improved information exchange with their physician.[152] Two other studies noted an improved dialogue and conversation between physicians and patients,[151, 153] in one case as a result of “up-to-date information” provided by the system.[153]

Seven studies found results relating to acceptance of the systems.[151, 152, 155, 157, 160, 161] Two studies found that the majority of users felt that the program had a positive impact on patients[151, 155] and that it saved the physicians time.[155] Another reported that several patients wanted to spend over an hour learning from the system.[152] In four studies, the amount of software use indicated its acceptance. One found that two-thirds of clinicians with access to the application used it on average 4 times per month;[151] another study found that over 80 percent of physicians had used the health IT application at least 10 times in the last year.[155] One study found that use of the system increased, reaching a maximum at the end of the research period, and that most physicians wanted to continue using the software, though some desired small modifications to be made.[161] However, one study found that only 1 out of 10 offices incorporated the patient education program into their workflow, perhaps because patients were intimidated by the computer and staff did not encourage its use.[154] Several studies reported on willingness to recommend the system. One found that 79 percent of physicians had recommended the system to other potential users,[157] and another that 99 percent of users were willing to recommend it.[160] A third study found that over 80 percent of patients using the application said they would recommend it to a friend.[152] Also, all patients in this study said that they would use the application again if they were asked to and that it was "worth the trouble" (p. 148) of using it.[152] Seven articles discussed issues related to the system's usability.[151-155, 158, 161] Four studies noted positive characteristics of applications that were easy to use.[152, 155, 158, 161] One of these studies[155] reported that the system's usefulness was due to the selection of included material by physicians who were familiar with the information needs of end users. This system was designed to be "one-stop shopping" (p. 274). Another study reported that users' difficulty in finding information led to frustration,[153] and a third study found that a search function was difficult to use because it lacked spell checking.[158] In one study, patient users found at least some of the information confusing.[152] The requirement that physicians re-enter patient data led to one application not being used.[151] Another study[154] found that an application was disruptive to the office visit because patients spent approximately 10 minutes using it prior to seeing the physician and were not finished when the physician was ready to see them. This disruption to the schedule "placed an additional time burden on staff who already felt overworked" (p. 43).

Summary. Overall, a diverse group of information resource applications were described in the literature. Three of these articles examined the effect of the health IT on the knowledge of end users; all found positive effects. Information resource applications were also found to be well accepted, with one exception.[154] Many systems were described as easy to use, although some usability issues were reported, such as difficulties in finding information, duplicate data entry being required, and workflow disruptions related to the time required to use the system.

Other Health IT Applications

Other articles described the effect of health IT implementation on ambulatory workflow. The applications whose effects were analyzed varied widely, including digital imaging;[162-167] data feedback systems;[168, 169] a disease registry network;[170] an electronic health records search function;[21] an e-mail triage system;[171] health information exchange (HIE);[172-174] immunization registries;[175] patient access systems;[176, 177] secure messaging;[178] and the use of handheld computers for clinical applications including writing and transmitting prescriptions, capturing charges, accessing reference resources, performing research tasks and completing educational activities.[179] Several articles described decision support systems related to advanced directives,[180] coding terminology,[158] depression screening,[40, 181, 182] diagnosis support,[183-187] potential adverse drug events,[188-190] test ordering,[191, 192] triage decisions,[193] use by nurses,[194] guideline adherence not previously discussed,[195-197] or an unknown topic.[198] Other articles were systematic literature reviews of health IT in general,[60, 199, 200] or discussions of all types of decision support systems.[43, 45, 56, 201-209] Further information on the workflow changes described in these articles is available in the "research" database in the toolkit.

Use of Health IT as a Tool to Analyze and Redesign Workflow

Health IT applications have the potential to be a powerful tool for analyzing and redesigning workflows. Using health IT, practices can improve work processes to make them safer, improve their quality, and maximize efficiency. Health IT applications collect and store information relevant to many of the proximal measures of workflow previously discussed (see Table 1) including efficiency, information and people flow, communication, and coordination of care. Health IT often records and stores workflow data automatically, without the need for additional end user data entry but solely based on user actions taken within the system. For example, some EHR systems log users' actions, such as order entry, with date and time stamps, and the person performing the action. Thus, valuable data about the timing of events and who performed them is frequently available from health IT systems, information that is rarely available for nonelectronic data. One potential advantage of using health IT is that data are often stored in discrete fields and therefore can be retrieved and even analyzed in an automated fashion. This could obviate the need for a human to manually review the patient record, find the needed information, and record the information in a separate database for analysis, thereby decreasing the likelihood of errors of omission and data re-entry. It also reduces the human resources required for data collection. Health IT also has the potential to allow performance measurement, quality reporting, and to assist in providing population-based care through the use of registries. New models of care rely heavily on health IT to provide patient-centered, high quality of care.[210] However, currently many health IT systems are not designed to allow clinicians to easily abstract data to improve their workflows or the quality of care they provide.[211, 212]

The goal of this synthesis is to gain a better understanding of how health IT is being used as a tool to evaluate workflow in ambulatory clinics. This synthesis includes articles found in the literature review that:

- Use data from a health IT system implemented in an ambulatory clinic;
- Collect data from the health IT system in an automated fashion (data may be analyzed in an automated fashion or manually);
- Use the data obtained from the health IT system to evaluate workflow; and
- Evaluate proximal measures of workflow.

Articles with distal measures were only included in this analysis if proximal measures were also evaluated. In addition, patient and organizational outcome measures collected from health IT are noted. All articles were reviewed and the use of health IT as a tool was documented. These evaluations were then categorized into proximal, distal or outcome measures. The proximal measures were further classified into categories of workflow evaluation like those used for the literature review database.

There were 54 articles describing the use of health IT as a tool to evaluate clinic workflow (see Table 8). Thirty of these articles primarily evaluated the impact of a decision support system; 11 evaluated telemedicine workflow, 4 evaluated EHRs; 3 evaluated electronically available informational resources; and 1 article each evaluated e-prescribing, electronic search functionality in an EHR, and an e-prescription renewal system. Three of the articles evaluated more than one type of health IT. These articles utilized a qualitative data collection and analysis approach.

Table 8: Types of health IT used as a tool

Type of Health IT	Number of Articles	Percentage of articles
EHR/EMR	4	7.4%
Decision Support Systems	30	55.6%
Electronic Prescribing	1	1.9%
Telemedicine	11	20.4%
Informational Resources	3	5.6%
Other	2	3.7%
More than one type	3	5.6%
TOTAL	54	100.0%

Other studies have evaluated usage based on how often the goal of health IT use is met (see Table 9). For example, the use of e-prescribing[95] or electronic laboratory order forms[191] instead of paper forms, the use of a CDS tool for depression screening,[181] or the use of an EHR,[168] telemedicine,[114, 141] or prescription renewal system[94] to document patient information. Some articles documented the use of telemedicine by evaluating the frequency and type of information uploaded into the system, e.g., physicians sending and receiving referrals,[145] and patients entering blood pressure readings,[146] asthma medication use videos and symptom diaries,[119] or the answers to health related questions.[140]

Table 9: Types of proximal workflow measures evaluated using health IT as a tool

Type of Proximal Measure	Number of Articles	Percentage of articles
Usage	32	59.3%
Time	14	25.9%
Decision Support Functioning	19	35.2%
Decision Support Adherence	4	7.4%
Acceptance	2	3.7%
System Functioning	3	5.6%

Health IT has also been used as a tool to evaluate provider response to CDS reminders and alerts. Use has been evaluated based on whether or not a provider responds to reminders, e.g., calculating a response rate or completion rate of the reminders.[75, 77, 84, 96, 198, 207] In addition, the actions taken to respond to a reminder or alert have been evaluated,[81, 84, 90, 182, 195, 198] for example, whether the reminder was overridden/cancelled or accepted. At times, the CDS design also allows users to enter information about the CDS tool or the specific reminder or alert, e.g., why an alert was overridden.[62, 90, 181, 191]

Time. Fourteen articles evaluated aspects of time related to the use of health IT. These include the processing time for a CDS tool to review patient information and present recommendations,[71, 189] or the processing time for a digital radiology image to become available for physician interpretation.[213] Physician/provider and staff time have also been measured. Examples are the number of telemedicine days or sessions per week on the clinic schedule,[141] physician time spent reviewing informational resources[161] or CDS recommendations,[71] the time elapsed from when the CDS alert is presented until the physician/provider responds[182] or takes action on the CDS recommendation,[182] physician time spent taking digital photographs and entering data into the computer for a telemedicine consultation,[112] or staff time spent to assist a patient using a CDS tool.[201] In addition, patient time and distance traveled are measured for telemedicine consultations and compared to those of conventional clinic visits.[141] Lastly, the time for completion of a process or task in its entirety has been measured. For telemedicine consultations, these measures include the time until an intervention was performed,[115] an appointment was scheduled,[141] or a study was received, interpreted and the results sent back to the referring provider.[214] For CDS these measures were the duration of a task using the CDS system compared to without using the CDS system,[193] the time elapsed between a CDS alert about ordering lab tests and the lab result appearing,[188] or the time elapsed from an alert to the ordering of a guideline recommended medication.[63]

Decision support functioning. Many articles also used data from a health IT system to assess an aspect of CDS functioning, such as the end user's frequency of receiving CDS alerts or reminders and the types of alerts or reminders received. Most commonly, the total number of alerts or reminders sent to physicians/providers[69, 73, 77, 146, 188, 196, 198, 201, 215] or to patients[146] were evaluated. Many studies also evaluated the number of recommendations or alerts by type of alert,[69, 73, 90, 189] by severity,[90, 196] or by the recommendation generated.[196] The number of CDS alerts and reminders has also been evaluated at many levels of analysis: at the physician level (e.g., the number of reminders per physician[76]), at the patient level (e.g., the number of patients eligible for a reminder,[189] the number of reminders, alerts, or opportunities per patient,[66, 188, 201] or the number of indications for alerts per patient[77]), at an encounter level (e.g., the number of patient visits with asthma CDS trigger in record and the number of patient visits with recommendations given[71] or the number of patient visits with reminders per physician[76]), and on a practice level (e.g., the number of times the guidelines for patient care were triggered during a patient encounter for each practice.[68]) Most of these studies used health IT as a tool to evaluate the CDS intervention during a research study; however, others could use this data for nonresearch purposes to better understand provider workflow related to receiving CDS alerts and reminders.

Finally, health IT has been used to evaluate other decision support functions, such as the content of a hypothesis list presented to a user from an informational resource that assists with diagnosis[186] and the ability to identify preventable adverse drug events from an EHR.[21]

Adherence to CDS recommended actions. Health IT has been used to evaluate the physician or provider adherence to the CDS recommendations, e.g., test ordering in accordance to guidelines,[76, 195] prescriptions written based on a recommended medication[63] or duration of treatment,[97] or a recommendation to not prescribe a medication.[97] These articles carefully followed the actions of the physician or provider after interacting with the CDS to evaluate their actions within a specific time period. This method allows the studies to reasonably assume that the actions were related to the interaction of the physicians with CDS.

Other proximal measures. Two other proximal measures were less commonly evaluated using health IT: acceptance and health IT system functioning of applications other than decision support. One study programmed a satisfaction questionnaire into the telemedicine system and evaluated parent satisfaction with the use of the system and with the time required to perform the electronic data entry.[119] Another programmed patient and physician questionnaires into the tele-dermatology system in order to evaluate satisfaction with the system and confidence in the generated diagnosis and treatment plan.[114] As part of a telemedicine study on diabetes, researchers evaluated the accuracy of blood sugars relayed by patients over the telephone by comparing these to blood sugar values obtained from a glucose meter and uploaded into the system using a modem.[121] Another research team used a call management system to evaluate the number of telephone calls being handled per day and the time of day the calls were placed.[193]

Observational studies. Four articles discussed the use of health IT as a tool using qualitative and quantitative data from interviews, focus groups and surveys[38, 47, 49] and/or literature reviews.[44, 49] These articles discussed changes to physician time utilization,[44] improved ability to perform surveillance and monitoring for disease conditions and care delivery,[44] improved adherence to guidelines and protocols,[44, 47, 49] increased billing revenue due to increased service capture and increased level of coding based on documentation,[47, 49] improved tracking of test status and test results,[47] improved timeliness, availability and accuracy of messages within the organization,[47] decreased documentation errors[47] and increased completion of documentation.[47] However, it is difficult to tell from the articles whether the data used to draw these conclusions originated from the health IT system.

Distal workflow measures and outcome measures. Although distal workflow or outcomes measures were not the main focus of this synthesis, some articles used health IT as a tool to assess proximal measures of workflow and distal or outcome measures. Twenty-one articles measured distal workflow and 10 articles measured outcome. Examples of distal measures include ordering or performance of laboratory or diagnostic tests,[38, 68, 69, 71, 73, 77, 188, 196, 201] or the prescription or discontinuation a medication.[68, 69, 71, 73, 77, 91, 119, 168, 196, 215] In some cases, data originated from claims databases rather than health IT in the clinic. Further discussion on distal process measures and outcome measures can be found in a later section of this report.

Limitations. The analysis in this section has some limitations. Journal articles are not always explicit about the source of the data or whether the data is extracted from the health IT system in an automated fashion, so studies may have been excluded from the analysis that actually used health IT as a tool. More often, we found in our review of the articles that data were collected manually from an EHR in lieu of automated data collection. This fact may reflect the limited capabilities of the health IT system and the end users inability to easily and reliably abstract the data automatically.

Articles Using Distal Measures of Workflow

Our literature review identified a number of studies that measured the impact of health IT on various care processes and outcomes, but not directly on workflow. Our literature review was not designed to systematically address the impact of health IT on distal measures of care processes and outcomes measures; therefore, we did not review these papers in a systematic manner. In this section, we describe examples of the studies that reported on distal measures of workflow; we also provide some potential explanation of how these distal measures may have been influenced by changes in workflow.

Health IT Other than Telemedicine

Our literature review identified 54 papers on health IT, other than telemedicine, and distal measures of workflow:

- 10 literature review papers
- 15 papers on preventive services
- 9 papers on adherence to guidelines and procedures
- 8 papers on patients with cardiac conditions and for hypertension management
- 6 papers on medication prescription
- 6 papers on testing performance (e.g., childhood immunization and HIV testing) and efficiency of test ordering.

The majority of the literature review papers were published after 2000. Several literature review papers selected to review only RCTs in various areas, such as health IT in both ambulatory and inpatient settings,[216] CDS,[217, 218] preventive care,[219] and computerized reminders and feedback in medication management.[220] The literature review papers focused on various areas: preventive care,[219, 221] medication management,[220, 222] guideline implementation,[223] CDS in general,[217, 224] and CDS for specific conditions such as osteoporosis.[218]

The 15 studies on preventive services typically reported on the impact of health IT on the percent of patients who received preventive services. For instance, numerous studies examined the impact of computerized feedback and reminders to providers on screening for blood pressure, cholesterol and other conditions,[225-230] and mammogram ordering.[231, 232] The increases in screening that occurred as a result of the computerized feedback and reminders were likely due to changes in the workflow in the practices, such as the work of providers (e.g., access to computerized recommendations for specific patients at the time of the visit). However, these studies did not provide information on the changes in workflow that occur as a consequence of the implementation of computerized feedback and reminders.

The nine studies that examined adherence to guidelines often provided the guidelines in an electronic format, such as using a personal digital assistant (PDA).[233, 234] The guidelines covered various issues, such as management of HIV infection,[235] management of asthma,[234] identification of latent tuberculosis infection,[236] osteoporosis management after a fracture,[237] and treatment of diabetic patients.[12]

Eight studies focused on the care of patients with cardiac problems,[238-241] hypertension management,[242-244] and cardiovascular disease risk assessment.[245] These studies evaluated the impact of the health IT interventions on various process and outcome measures related to cardiovascular conditions (e.g., blood pressure).

Six studies examined the impact of health IT on medication prescription, such as in ambulatory pediatrics[246] and for diabetic patients.[247, 248] These studies examined the extent to which prescriptions were ordered according to evidence,[246, 248] the appropriateness and safety of medication prescribing,[249, 250] and changes made to the medication regimen.[247] It is very likely that these health IT interventions involved changes in the workflow, in particular the cognitive workflow of physicians who changed their prescribing behaviors.

Four studies focused on the impact of health IT (e.g., alerts) on testing performance, including influenza vaccination,[251, 252] childhood immunization,[253] and HIV testing.[254] Two studies focused on the efficiency in test ordering.[255, 256]

Telemedicine Articles Using Distal Measures of Workflow

A total of 11 studies examined various forms of telemedicine such as providing an ear, nose and throat (ENT) consultation,[257] neurology consultation[258] or a range of specialists,[259-261] providing access to mental health specialists[262] or nurses,[263] and tele-monitoring of patients at home.[264-267] These studies examined a range of process and outcomes measures:

- Costs,[257, 259-261, 264] including cost to patients;[257, 260]
- Number of tests ordered;[258]
- Various indicators of physical and mental health for patients with depression;[262, 263]
- Various physiological indicators for home-monitored cardiac patients such as blood pressure and heart rate;[265, 266] and
- Diagnosis performed by the tele-cardiology specialists.[267]

Conclusion

This chapter summarizes our evaluation of the peer-reviewed literature on workflow changes related to health IT implementation and use of health IT as a tool to analyze workflow. Although we aimed to review as much of this literature on these topics as possible, we may have missed some articles. To identify a reasonable amount of literature to review, we selected three sets of search terms—on ambulatory care, health IT and workflow—and searched the conjunction of the three. As we learned in reading articles identified through a search of systematic literature reviews on health IT implementation, however, several authors discussed workflow changes without explicitly using any of our workflow search terms in the abstract or title. Such articles could have been missed by our search, even though we reviewed almost 4,500 articles.

In doing this review, we also gave careful consideration to what "workflow" is, and realized that some measures of workflow change—distal and outcome measures—suggest the types of process changes that have occurred but do not provide enough information about those changes. We therefore chose to focus on proximal measures of workflow change—those that describe how processes have been modified. We have compiled the information on these proximal measures of change into syntheses describing the effects of implementation for several types of health IT: EHR/EMR and CPOE; decision support systems on chronic disease management, preventive care, and medication prescribing; electronic prescribing; telemedicine; information resources; and the use of health IT as a tool. We also briefly describe a selection of articles using distal process measures and outcome measures of workflow to provide a sense of the issues that these articles address.

Detailed information on each article in the literature review and its findings are described in the database of published papers in the toolkit. This information was also used to inform the toolkit's design and content.

Chapter 3. Environmental Scan

Background

The purpose of the environmental scan was to learn what others were doing regarding health IT implementation and workflow in small and medium-sized ambulatory care practices. The objectives included identifying:

- User stories on workflow issues encountered in the development, implementation, adoption and use of health IT, and
- Publicly available workflow design tools and methods applicable to ambulatory practice workflow analysis and redesign or related initiatives, including redesign efforts that use health IT as a tool.

The project team followed a three-step approach to conduct the environmental scan:

1. Identification of key health care organizations and associations. Based on the expertise of project team members, feedback from AHRQ, and suggestions made by the project consultants, a list of organizations and associations was compiled. Information regarding the organizations and associations was gathered from various resources and if more information was necessary, additional follow-up was conducted.
2. A broad, comprehensive Web-based search on small and medium-sized ambulatory care clinics, workflow, and health IT. Using the literature search terms, focused and nonsystematic searches were conducted on the World Wide Web. A snowball technique was used as a Web site would often refer to relevant resources on another Web site. Resources involving a user story or tool were recorded in the EndNote® database and key information documented in a Microsoft® Office Access 2000 database.
3. Comprehensive literature search. A total of 13 literature databases were searched using synonymous key terms for 'ambulatory care,' 'health IT' and 'workflow'. Detailed instructions regarding the methodology of the literature search can be found in the Chapter 2. Both peer-reviewed and nonpeer-reviewed references containing user stories and tools relevant to the objectives of the environmental scan were recorded in an EndNote® database and key information documented.

Relevant tools were also identified in a book search in WorldCat using the same terms used in the literature search and books recommended by the research team, TEP, and consultants. The references were recorded in the EndNote® database and key information documented.

Key Organizations and Associations

Methods

With the enactment of the American Recovery and Reinvestment Act of 2009 (ARRA) and the Health Information Technology for Economic and Clinical Health (HITECH) Act provisions contained within ARRA, many organizations and associations are interested in issues related to health IT. Identification of key organizations and associations for this project began with a

brainstorming session by project team members. Two project consultants and AHRQ then provided feedback to complete the list. Additional organizations and associations were identified through focused Web searches using key terms identified in the literature search methodology. A snowball technique was used in the focused Web searches as key organizations were identified through the discovery of a reference on the Web sites of a previously identified key organization. Data was collected through Web site review; follow-up was conducted if more information was necessary. Information was summarized and recorded in electronic documents.
Organizations and associations were considered ‘key’ if they focused on issues pertaining to small and medium-sized ambulatory care clinics, health IT, and workflow. Many covered the first two topics but did not include information regarding workflow. Detailed information follows only for those organizations and associations that addressed all three topics. Workflow issues and advice from organizations and associations are also highlighted. All organizations and associations reviewed are referenced in Appendix C.

Table 10 lists the missions/goals and URL of each organization and association. Detailed information for each follows the table.

Table 10: Organization mission/goals and URL

Organization category	Organization	Mission/Goals of the Organization	Website URL
Federal Government Agencies	Agency for Healthcare Research and Quality (AHRQ)—Health IT Initiative	The mission of the Agency for Healthcare Research and Quality (AHRQ) is to improve the quality, safety, efficiency and effectiveness of health care for all Americans. The Agency has focused its health IT activities on the following three goals: (1) improve health care decisionmaking, (2) support patient-centered care, and (3) improve the quality and safety of medication management.	http://healthit.ahrq.gov
	Health Resources and Services Administration (HRSA) - Office of Health Information Technology and Quality (OHITQ)[a]	The Health Resources and Services Administration (HRSA) is the primary Federal agency for improving access to health care services for people who are uninsured, isolated or medically vulnerable. HRSA's Office of Health Information Technology and Quality (OHITQ) seeks to improve the quality of health care for safety net populations and strengthen the health workforce that serves these populations.	http://www.hrsa.gov/publichealth/business/healthit/
	Office of the National Coordinator for Health Information Technology (ONC)	The Office of the National Coordinator for Health Information Technology (ONC) is at the forefront of the administration's health IT efforts and is a resource to the entire health system to support the adoption of health information technology and the promotion of nationwide health information exchange to improve health care.	http://healthit.hhs.gov
	Centers for Medicare & Medicaid Services (CMS)	To ensure effective, up-to-date health care coverage and to promote quality care for beneficiaries.	http://www.cms.hhs.gov/
National Organizations And Associations	American Academy of Family Physicians (AAFP)'s Center for Health Information Technology	The American Academy of Family Physicians (AAFP) was founded in 1947 to preserve and promote family medicine and to ensure high-quality, cost-effective health care for patients.	http://www.aafp.org/online/en/home.html

Organization category	Organization	Mission/Goals of the Organization	Website URL
	American Academy of Pediatrics (AAP)	The American Academy of Pediatrics (AAP) is committed to optimal physical, mental, and social health and well-being of infants through young adults.	http://www.aap.org/
	American College of Physicians (ACP)	The American College of Physicians (ACP) is a national organization whose members include internists, internal medicine subspecialists, medical students, residents, and fellows. ACP has several major initiatives involving the medical home, medical informatics and workflow analysis.	http://www.acponline.org/
	American Medical Association (AMA)	The American Medical Association (AMA) was founded in 1847 by Dr. Nathan Smith Davis. Its mission is to promote medicine and the improvement of public health.	http://www.ama-assn.org/
	American Medical Informatics Association (AMIA)	The American Medical Informatics Association (AMIA) promotes organization, analysis, management, and use of information to support health care. Members of AMIA promote health IT in clinical care and clinical research, personal health management, public health/population health, and translational science to improve health.	https://www.amia.org/
	Association of Medical Directors of Information Systems (AMDIS)	The Association of Medical Directors of Information Systems (AMDIS) was formed to advance the field of applied medical informatics. AMDIS is the professional organization for physicians interested and involved in health IT. AMDIS members are the leaders and decision-makers in their field.	http://www.amdis.org
	The Center for Improving Medication Management	The Center for Improving Medication Management provides a collaborative forum to establish priorities for projects that demonstrate the value of pharmacy interoperability to improve medication management. Founding groups of the center include AAFP, Humana, Intel Corporation, MGMA, and Surescripts.	http://www.thecimm.org/
	Certification Commission for Healthcare Information Technology (CCHIT®)	The Certification Commission for Health Information Technology (CCHIT®) strives to improve the quality, safety, efficiency, and access of health IT with the goal to accelerate its adoption.	http://www.cchit.org/

Organization category	Organization	Mission/Goals of the Organization	Website URL
	eHealth Initiative	The mission of the eHealth Initiative is to "to drive improvement in the quality, safety, and efficiency of health care through information and information technology." The organization focuses on engaging stakeholders to address health care system challenges through the use of IT. The eHealth Initiative is involved in information therapy, e-prescribing, drug safety, care coordination, and comparative effectiveness.	http://www.ehealthinitiative.org/
	Healthcare Information and Management Systems Society (HIMSS)	The Healthcare Information and Management Systems Society (HIMSS) provides leadership on the optimal use of IT and management systems for improving health care.	http://www.himss.org/ASP/aboutHimssHome.asp
	Institute for Healthcare Improvement (IHI)	The Institute for Healthcare Improvement (IHI) is an organization dedicated to the improvement of health care throughout the world. IHI is improving health care by "building the will for change, cultivating promising concepts for improving patient care, and helping health care systems put those ideas into action."	http://www.ihi.org
	Medical Group Management Association (MGMA)	The Medical Group Management Association (MGMA) is dedicated to improving the performance of medical group practice professionals and the organizations they represent.	http://www.mgma.com/
Quality Improvement Organizations (QIOs)	Colorado Foundation for Medical Care (CFMC)	The Colorado Foundation for Medical Care (CFMC) is the QIO of Colorado. CFMC works to improve the quality of health care by collaborating with government programs, health providers, and managed care companies. The CFMC was funded by the Centers for Medicare & Medicaid Services to examine workflow in the context of EHR adoption.	http://www.cfmc.org/
	Illinois Foundation for Quality Health Care (IFQHC)	The Illinois Foundation for Quality Health Care (IFQHC) is the QIO of Illinois and provides assistance to Medicare consumers and health care providers who participate in the Medicare program.	http://www.ifqhc.org/

Organization category	Organization	Mission/Goals of the Organization	Website URL
	MetaStar	MetaStar is the QIO of Wisconsin that works with health care providers to improve the quality of care. Metastar believes health care should be patient-centered, safe, effective, timely, efficient and equitable. They bring providers together to collaborate and learn from one another.	http://www.metastar.com
State-level Organizations And Associations	Massachusetts eHealth Collaborative	The Massachusetts eHealth Collaborative was formed by the physician community "to bring togetherthe s tate's major health care stakeholders for the purpose of establishing an EHR system that would enhance the quality, efficiency and safety of care in Massachusetts."	http://www.maehc.org/
	Michigan Improving Performance In Practice (IPIP)	The Michigan Improving Performance In Practice (IPIP) is funded by a Michigan State public health grant to help primary care practices in process improvement.	http://ipip.aiag.org/
	New York Primary Care Information Project (PCIP)	The Primary Care Information Project (PCIP) works to improve health care through health IT and data exchange. The program supports the adoption and use of EHRs among primary care providers in the underserved communities of New York City.	http://www.nyc.gov/html/doh/html/pcip/pcip.shtml
	Wisconsin Medical Society (WMS)	The Wisconsin Medical Society (WMS) is the largest association of physicians in Wisconsin and is a trusted source for health policy leadership.	http://www.wisconsinmedicalsociety.org/
Non-Health care Organizations and Associations	American Society for Quality (ASQ)	ASQ is a community of experts that "advances professional development, credentials, knowledge and information services, membership community, and advocacy on behalf of its more than 85,000 members worldwide. As champion of the quality movement, ASQ members are driven by a sense of responsibility to enrich their lives, to improve their workplaces and communities, and to make the world a better place by applying quality tools, techniques, and systems."	http://www.asq.org/
	Carnegie Mellon Center for Computational Analysis of Social and Organizational Systems (CASOS)	CASOS combines computer science, dynamic network analysis and the empirical study of complex socio-technical systems.	http://www.casos.cs.cmu.edu

Organization category	Organization	Mission/Goals of the Organization	Website URL
	Institute of Industrial Engineers (IIE) and the Society for Health Systems (SHS)	The Institute of Industrial Engineers (IIE) is a professional society dedicated to the advancement of technical and managerial excellence of industrial engineers. The Society for Health Systems (SHS) is a society of IIE that enhances career development and continuing education of industrial engineering professionals working in the health care industry.	http://www.iienet.org
Other Organizations	Surescripts	Surescripts, a privately owned business entity, operates a national infrastructure that enables the exchange of information on patient pharmacy benefits and prescriptions.	http://www.surescripts.com
	Upstate Neurology Consultants, LLP	Upstate Neurology physicians are “specialists in the medical care of the brain, spine, peripheral nerves, and muscles.”	http://www.upstateneurology.com/

[a]The Health IT Toolbox had been located at the AHRQ National Resource Center for Health IT Web site but has since migrated to HRSA’s OHITQ Web site. HRSA-OHITQ is listed in Table 10 to reference its URL.

Federal Government Agencies

U.S. Department of Health and Human Services (http://www.hhs.gov/)

Agency for Healthcare Research and Quality (AHRQ)—Health IT Initiative: AHRQ's Health IT Initiative's Web site, the National Resource Center for Health Information Technology, includes health IT tools, a knowledge library, funding opportunities, and FAQs.
The following resources regarding workflow, which are available at http://healthit.ahrq.gov/tools, are of particular interest:

- The Time and Motion Database is a tool that evaluates workflow efficiencies by capturing how time is spent on clinical and administrative tasks. The tool can be used to measure time spent on tasks such as time spent per patient, time spent on medication orders, medication turnaround times, nurse time spent on direct patient care and other measures. The *Journal of Biomedical Informatics* published an article, "Primary care physician time utilization before and after implementation of an electronic health record: A time-motion study",[26] that provides relevant information on the use of time-motion studies in primary care.
- The Health IT Evaluation Toolkit[268] references the Canada Health Infoway Benefits Evaluation Indicators Technical Report.[269] The toolkit and report discuss methods such as observations, time and motion studies, interviews and focus groups for evaluating workflow efficiencies, e.g., patient throughput and percentage of orders requiring a pharmacy callback.
- The Quick Reference Guides for Health IT Evaluation Measures provide details on workflow measures that can be used to evaluate health IT. Measures include impact of health IT on nurses' time spent on direct patient care, length of stay, patient use of secure messaging, prescribing patterns of preferred or formulary medications, improved accuracy of coding, percentage of alerts or reminders that resulted in desired action, and others.

Health Resources and Services Administration (HRSA) - Office of Health Information Technology and Quality (OHITQ): HRSA's Office of Health Information Technology and Quality (OHITQ)'s Web site includes several resources under its Health IT Toolbox, one of which is of particular interest:

- The Health IT Adoption Toolbox contains workflow analysis and redesign worksheets and diagrams in 'Planning for Technology Implementation.' The worksheets and diagrams are designed to develop a visual representation of the current state of work and assist in the redesign of processes such as patient visits.

The Health IT Toolbox had been located at the AHRQ National Resource Center for Health IT Website but has since migrated to HRSA's OHITQ Website. Details about this toolbox arenow listed under HRSA-OHITQ.

Office of the National Coordinator for Health Information Technology (ONC): ONC's Web site covers topics such as funding opportunities, regulations and guidelines, ONC initiatives and a health IT tools Web page for CDS, EMR, e-prescribing, personal health records, remote monitoring, secure messaging, and telehealth. The health IT tools Web page provides brief descriptions of types of health IT applications and resources/links for additional information on each type.

Of particular interest are the Health Information Technology Regional Extension Centers (RECs) and the national Health Information Technology Research Center (HITRC) authorized by the HITECH Act. The RECs will provide assistance (including workflow analysis and redesign) to health care providers for EHR adoption, use, and provider support. Additionally, Curriculum Research Centers will support health IT curriculum development that will enhance programs of workforce training primarily at the community college level. The curriculum will include training in the fundamentals of 'Health Workflow Process Analysis and Redesign' in addition to 19 other health IT curriculum areas such as working with health IT systems, installation and maintenance of health IT systems, and quality improvement.

Centers for Medicare & Medicaid Services (CMS): CMS has contracted a number of demonstration projects and initiatives on health IT. CMS created a demonstration initiative that rewards physician practices for delivering high-quality care through the use of EHRs. Additionally, CMS, as authorized by the Medicare Improvements for Patients and Providers Act of 2008 (MIPPA), offers an Electronic Prescribing (eRx) Incentive Program where eligible practices may quality for an incentive payment for meeting specified success criteria.

Of particular interest is the Doctor's Office Quality Information Technology (DOQ-IT) University. The DOQ-IT University was launched in 2007 by CMS to provide guidelines and recommendations to clinical practices for the adoption and implementation of EHR and care management. Masspro was selected by the CMS to develop the DOQ-IT University. They provide EHR readiness assessments that practices can use to evaluate themselves, white papers that describe required characteristics for EHR systems and guidelines for contracting with EHR vendors.

DOQ-IT University also offers a workbook, A Systems Approach to Operational Redesign,[270] which provides an introduction to operational redesign. Its purpose is to help practices evaluate current state workflows and identify areas to improve upon or change with the implementation of health IT. The workbook targets four key workflow areas for redesign: patient flow, point of care documentation, in-office communication, and documentation management. Each workflow area is highlighted by providing an overview, a methodology to evaluate current and future workflow states and a plan to develop the new state. Tools such as questionnaires and check lists are used for evaluating current workflows and tools such as process flows are suggested for future workflow states. Best practice recommendations are also provided.

National Organizations or Associations

American Academy of Family Physicians (AAFP)'s Center for Health Information Technology: To assist family physicians in the transition to health IT systems, the AAFP's Center for Health Information Technology provides information resources, interactive tools and a network of colleagues in the U.S. and around the world who have successfully implemented EHRs. The Web site includes information on various government incentives, standards development and other projects. Some links are publicly available and others are available to members only.

Of particular interest is their EHR Adoption web page that discusses details on four phases of adoption: preparation, selection, implementation, and maintenance. The importance of studying workflow issues such as inefficiencies, duplicated effort, and wasted time is emphasized. Examples include time spent on the phone following up with the pharmacy on medication changes or refills, delays in locating paper records, delays in locating outside lab results, or costs associated with transcription. An article, "Strategies for Better Patient Flow and Cycle Time",[271] discusses, amongst other topics, tools for evaluating patient care processes such as flow mapping, cycle-time measurement, and creating interruption lists. They also reference the Institute for Healthcare Improvement (IHI) Patient Cycle Tool that can be used to evaluate the time spent by a patient in the office.

In their Implementation 201 Web page, AAFP suggests that selecting the correct health IT application is only one factor in success. Other factors include understanding office functionality and addressing any redesign issues. They describe two categories of workflow: the flow of patients and the flow of patient information. Suggestions to consider for enhancing patient flow include implementing kiosks for patients to access, providing the ability to fax and printing patient information in the exam room and others. To enhance the flow of patient information they suggest robust electronic messaging systems.

American Academy of Pediatrics (AAP): AAP has a toolkit, "Implementing an Electronic Health Record," that is available to their members. They also have a course, "Electronic Health Records in Primary Pediatric Care," available for purchase that covers topics including benefits and barriers of adoption EHR systems, questions for pediatric primary care practices to consider, plans to address technical, organizational, and economic challenges in EHR implementation, evaluating EHR products and identifying resources. They have a Web site where members can rate their EHR performance and share experiences with others.

AAP stresses the involvement of many users when addressing workflow. Beyond physicians and practice managers, it is important to involve other practice staff such as billers, triage nurses, receptionists, and all members of the practice team. AAP notes that some practices will even consult families because of their unique perspective on workflow patterns.

Suggestions include:

- Set up the exam room so the provider can face both the patient and computer at the same time.
- Utilize consultants to determine the necessary infrastructure for implementing health IT (e.g, what hardware to buy, building a network, backing up data, conform to privacy regulations, security, training staff).
- Invest in as much training as possible up front to avoid costly setbacks after the health IT is implemented.
- Evaluate the implementation of health IT through measures such as revenue, patient satisfaction, numbers of drug errors or interactions, office and staff efficiency (such as time to complete tasks), and others.

Comments include:

- Benefits of health IT include the ability to delegate tasks at the point of care, having clinical decision support resources available at the point of care, the ability to access data from many locations, and e-prescribing. Some of these benefits may have an increased burden of data entry.

- Interfaces may be necessary for exchanging data between applications. Examples include auxiliary systems for generating preventive care reminders, systems to translate data from an old health IT to a new health IT, systems for immunization or disease registries and laboratory systems.

American College of Physicians (ACP): The ACP practice management Web page contains many links to patient care and office forms. Included are forms and/or flowsheets for charting issues such as extended histories, medications, health maintenance, progress notes and others. There are also links to office signs and forms for screening and vaccinations.
The ACP health IT Web page contains articles, guides and toolkits pertaining to health IT selection, implementation and workflow analysis. Much of the information (toolkits and guides) is available only to ACP members—including the EHR Partners Program that conducts evaluations of vendor EHR systems. The Web page on EHR Adoption Road Map and Tools contains a number of tools including EHR evaluation and selection checklists, case studies and the "Advance Planning & Workflow Analysis" document that covers workflow considerations prior to EHR implementation. ACP has made a chapter available from the *Electronic Health Records*, 2nd Edition,[272] on starting the EHR selection process (chapter 14). This chapter mentions the need to fit the practice to the EHR product through a detailed analysis of how tasks are performed by staff members and then reengineering/redesigning the practice to accomplish its goals and complement the EHR.

The ACP Center for Practice Innovation and Improvement conducted workflow analysis coaching with approximately 30 small medical practices. They also interviewed physicians, practice staff and patients. The interview videos are publicly available and highlight issues such as how technology can improve care, efficiency in communication and challenges associated with operating small practices. Findings from this project revealed the following:

- Practice personnel did not respond to attempts at quality improvement using tools such as Plan-Do-Study-Act (PDSA) cycles and other formal tools for workflow analysis or change management. They did, however, respond to simple, step-by-step instructions. Rather than flow charts, practices would often provide text descriptions of patient flow.
- Practices that were only marginally profitable had a hard time performing any new tasks. It was necessary for them to first receive coaching on basic financial issues and how to improve income before even considering implementing workflow improvements.
- Many vendors use value added resellers (VARs) who are often responsible for implementation, training, and support. As a result, tools used in workflow analysis and redesign are often variable depending on who is responsible for health IT implementation, training, and support.
- Often, when a practice rushes to implement an EHR system, not enough time is spent properly analyzing and redesigning workflows. As a result, workarounds are implemented and these tend to be permanently integrated into the workflow. These workarounds can defeat the usefulness of the system.
- EHR vendors rarely provide support for higher level functionalities such as reporting patient safety measures, e-prescribing, electronic test results, alerts, and others.

Practices often learn to use these high-level functions through trial and error or user groups.

- From the perspective of a practice, publicly available implementation tools are not tailored enough to the specific EHR system being implemented. As a result, practices rely on vendor tools.

American Medical Association (AMA): The AMA ePrescribing Learning Center provides information on effectively planning for and implementing e-prescribing, calculating the impact on the practice, estimating the potential CMS incentive payment and the ability to view an e-prescribing vendor list based on identified needs. Common e-prescribing workflow issues are described. All documents, videos, and applications are publicly available.
Of particular interest is AMA's Web page dedicated to health IT. They provide information for selecting a health IT, implementing health IT, benefits and risks associated with health IT, self-assessment, and vendor assessment. They also provide general information about health IT including current health IT debates such as privacy and security, interoperability, and quality improvement. Health IT resources and activities such as Webinars, the ePrescribing Learning Center, the CMS ePrescribing Incentive Program, and the AMA Health IT in the News are available. Regarding workflow, there are models, diagrams, and checklists for workflow assessment and redesign. These include assessments for front desk procedures, patient visit tasks for MAs, RNs, MDs, labs, referrals and check-out processes, prescription refills and phone calls. Several 'operational redesign' documents can be used to analyze patient flow, point of care documentation, in-office communication, document management, prescriptions and scheduling. AMA also provides links to guidelines for process mapping (from the DOQ-IT project) and documents addressing patient communication models, tips for exam room setup, and vendor contracting models.

American Medical Informatics Association (AMIA): AMIA's GotEHR? Web page lists several EHR resources. GotEHR? states that EHRs have the ability to improve the quality, safety and cost of health care services and that they can strengthen the patient-clinician relationship. GotEHR? resources include several papers such as "How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings."[31] This paper discusses the need to understand and document workflows within the practice such as how appointments are scheduled, activities during a patient visit, identifying processes after a patient visit, and the handling of unscheduled patient visits. The importance of identifying and testing workflows before implementing an EHR system can mitigate problems after going live with an EHR. The paper also emphasizes considering workflows for how the office will function during unanticipated system downtime. For redesigning workflows, basic principles include simplicity, accessibility for patients, safety, thorough documentation, and task delegation. Physicians should only do what no one else in the practice is able to.

AMIA conducts a CMIO Boot Camp where chief medical information officers (CMIOs) and others can learn how to make effective use of EHRs and qualify for Medicare and Medicaid incentives. The 2010 course schedule covers many topics including process redesign for EHR implementation.

Association of Medical Directors of Information Systems (AMDIS): AMDIS provides an e-journal, The Informatics Review, which publishes topics including health IT and workflow. Additionally, the Useful Links Web page provides information on decision support systems, computerized provider order entry, personal health records and others.

HIMSS along with AMDIS conduct a Physicians' IT Symposium where topics including planning, implementation, workflow, vendor guidance, and the legal aspects of EHRs are examined.

The Center for Improving Medication Management: The Center for Improving Medication Management "educates clinicians and their staff on the best approaches to implementing prescribing technology and integrating it with the day-to-day workflow". They emphasize that to automate the prescribing process it is necessary to adopt and use e-prescribing applications that have physician-pharmacy interoperability. The systems should also have the ability to improve patient adherence to prescribed medications. The Center conducts research in these areas.

The Center launched the "Get RxConnected" program in conjunction with the American Academy of Family Physicians, American Academy of Pediatrics, American Academy of Physician Assistants, American College of Cardiology, American College of Obstetricians and Gynecologists, American Osteopathic Association, and Medical Group Medical Association (MGMA). Get RxConnected helps to support practice efforts to secure an e-prescribing connection to their local pharmacies. If the practice has an EHR, Get RxConnected helps them determine the necessary functionalities in order to qualify for government programs such as Medicare Improvement for Patients and Providers Act (MIPPA). If the practice does not have an EHR, they provide technology assessment and a customized guide that lists e-prescribing solutions, questions to ask vendors and an estimate of time and money spent in faxing and calling in prescriptions—which e-prescribing automates.

Certification Commission for Healthcare Information Technology (CCHIT®): CCHIT provides an online library of presentations, town halls, comments and testimony, and education through workshops. Additionally, CCHIT certifies EHR systems. The CCHIT certification process ensures that health IT applications have specified capabilities that were defined through voluntary, consensus-based feedback from stakeholders.

eHealth Initiative: The eHealth Initiative provides a toolkit to support health IT and health information exchange (HIE) adoption. The toolkit provides information on (1) engaging the consumer, (2) organization and governance, and (3) value and sustainability. The toolkit includes public education tools to engage the consumer. 'Organization and governance' tools include a project planning tool, a readiness questionnaire, lessons learned, an interview template and evaluation tools. 'Value and sustainability' tools including a market readiness assessment tool, a risk adjusted discount rate tool, an HIE business value tool and a financial pro forma tool.

The eHealth Initiative published, in collaboration with The Center for Improving Medication Management, AMA, AAFP, ACP and MGMA, the Clinician's Guide to Electronic Prescribing.[273] Workflow benefits of e-prescribing include reduced time spent on phone calls and call-backs to pharmacies, reduced time in faxing prescriptions, automating prescription renewal and authorization, and greater prescriber mobility. Workflow challenges include additional time to complete new tasks (such as creating new prescriptions or capturing preferred pharmacy information at patient intake) and changes in roles in responsibilities (such as activities handled by staff in the past being taken on by the physician). The guide emphasizes that small practices would benefit from additional resources during the transition. Additionally, small or rural practices may encounter other challenges such as broadband connectivity and access to skilled professionals to assist in hardware selection and maintenance. Information is provided for assessing practice readiness, defining practice needs, understanding costs and financing options, and selecting and deploying systems. Additionally, they provide a list of technical and workflow issues others have encountered in the past and plausible solutions:

- Multiple requests for renewal
- Pharmacies not checking their e-prescribing system
- Pharmacies sending renewal requests in multiple manners, i.e., fax and e-Rx, causing confusion in the practice about which request to act on and lack of confidence that the system works
- Patients refusing e-prescribing as a result of a bad experience or because they do not know which pharmacy they will use
- Physicians questioning the advantage of e-prescribing over computer-generated faxing and feel it creates more work and potentially additional costs.

Healthcare Information and Management Systems Society (HIMSS): The HIMSS Topics & Tools Web page introduces pages for many topics including meaningful use, EHRs, clinical informatics, privacy and security, interoperability, standards, ambulatory IS, financial systems and resources from sponsors/partners.

The Electronic Health Record Web page addresses return on investment (ROI), standards, EHR adoption, tools for professionals, project management, case studies, and usability. HIMSS provides Davies Awards of Excellence that recognize "excellence in the implementation and value from health information technology, specifically EHRs."

The EHR Adoption Web page lists publications and presentations from 2007 to the present. A number of documents address usability such as the presentation, Clinicians, HIT and Usability that focuses on the principles of usability, potential current and future health IT and workflows, and introduces the HIMSS EHR Usability Task Force.

The HIMSS EHR Usability Task Force created the "Defining and Testing and EMR Usability: Principles and Proposed Methods of EMR Usability Evaluation and Rating"[274] document. This document defines usability principles in the context of EHRs including simplicity, naturalness, consistency, minimizing cognitive load, efficient interactions, forgiveness and feedback, effective use of language, effective information presentation, and preservation of context. There are usability and workflow evaluation and rating methods, including information for evaluating efficiency, effectiveness, ease of learning, cognitive load, and user satisfaction. Task evaluation is discussed along with challenges of evaluating usability due to the complex nature of user tasks and workflows. Workflow associated with a task is often a combination many steps. An example is provided for refilling a medication consisting of: prior information (medication history, last visit date, etc), future information (next lab or visit date), medical evidence personalized for the patient, contextualized relevance, task of creating/approving the refill, cost and formulary considerations, and communication with assistants or the pharmacy. Recommendations, references, and benchmark examples are also provided.

Of interest on the HIMSS Ambulatory Practice IS Web page are the sections on EMR Adoption and HIT Resources and Tools. HIMSS provides brochures for "Getting Started with an EMR" and "Selecting the Right EMR Vendor." For understanding the EMR, they provide links to several publications such as:

- A white paper, "EMR Implementation in Ambulatory Care."[275] The white paper discusses choosing an EMR, project management, health IT configuration, training, quality, and ROI. The paper presents cases of technology infrastructure such as how various users access the health IT (e.g., providers and nurses using tablet PCs and administrative personnel using terminals). The paper discusses project management skills for converting a practice from paper to health IT. This includes a brief discussion on analyzing workflow through mapping current practice processes and decisions for future states. The paper also discusses health IT configuration. There are many configuration issues to consider such as importing lists of local pharmacies, scanning paper notes and physician signatures, and security settings. The paper notes that, generally, configuration must be done by the clinicians and is quite costly.
- A document, "So You Are Thinking About Computerizing Your Office…" written by a physician with health IT implementation experience. The author emphasizes the following points: "quality does not (yet) pay," "go slow," "find a champion," "don't fixate on cost," "find a flexible system," and "be flexible yourself." Regarding "going slow," the suggestion is made to first start with changes that will improve workflow.

The HIT Resources and Tools Web page contains many documents such as the 2010 Ambulatory Fact Sheet, EMR/ROI Calculator, the HIMSS E-prescribing Wiki, the HIMSS E-prescribing Work Group, and many others.

The HIMSS Web page on e-Prescribing offers information on e-prescribing fundamentals, access to a wiki, a Web page on Implementation Challenges and Solutions, Quick Tips, and others.

The Management Engineering and Process Improvement (ME-PI) Web page offers access to information regarding the value of ME-PI and access to many tools that can be used in workflow analysis and redesign. While not all ME-PI tools are publicly available, included are tools and descriptions for benchmarking (e.g., a cycle time template, guidelines, etc.), change management tools (e.g., such as readiness assessments), lean six sigma, process management and mapping, charting (e.g., sample size calculator), and others.

HIMSS has a variety of publications regarding health IT. Health IT news is published in partnership with HIMSS and provides timely information regarding "new technologies, IT strategies and tactics, statutory and regulatory issues, as well as provider and vendor updates." There is a section that specifically targets ambulatory care practices. HIMSS also publishes Government Health IT. Topics include ambulatory care, EHR, e-prescribing, standards, telemedicine, and others.

HIMSS and AMDIS together formed the HIMSS Physician Community. The Community focuses on four areas including "tools, resources, education, research and professional development for physicians engaged in the development, implementation, and/or use of IT and management systems."

Institute for Healthcare Improvement (IHI): IHI has a Web page on improving workflow and removing waste in the clinical office so that an office can run efficiently and effectively. Tools are available to members and include:

- Minutes behind graph that shows the effect of staff hours,
- Patient cycle tool that collects data on the amount of time a patient spends at an office visit,

- Rooming criteria example that standardizes the process for rooming patients by diagnosis, and
- Standard room stocking checklist that leads to decreased re-work, high predictability of needs, and fewer interruptions.

There is also information for:

- Finding and removing bottlenecks,
- Removing intermediaries such as unnecessary involvement of staff in tasks,
- Using automation and technology,
- Moving steps in a system closer together such as physically moving staff closer together,
- Standardization,
- Just-in-time processing,
- Doing tasks in parallel,
- Synchronizing patient, provider and information,
- Using continuous flow to avoid batching such as doing work as it occurs to remove bottlenecks, and
- Reducing scheduling complexity.

The Group Visits 101 tool provides information for visit formats including sample handouts, space formats and coding for group visits—the information is available from chapter 9 of the book, What Works: Effective Tools and Case Studies to Improve Clinical Office Practices.[276]

Medical Group Management Association (MGMA): MGMA conducts research on health IT implementation. In 2005, they conducted a random nationwide survey of practices and, in 2007, a follow up survey of those that responded in 2005 was completed. Their research shows that the most successful practices are those that conduct workflow analysis prior to health IT implementation. Many workflow issues were identified including efficiency of staff, availability and accessibility of information, increased productivity, decrease in staff time and frustration, ability to see more patients, reduction in cost and wasted time, increased physician responsibility, redundant processes, integration with other health IT systems and many others. Findings also demonstrated that many practices had problems with connectivity and that small practices do not have the leverage to make others coordinate with them.

MGMA shared several tools used in workflow analysis including a billing process checklist, patient wait time benchmarks, medical record audit risk assessment, ROI for IT purchases, and a SWOT analysis tool. Additionally, MGMA provided an EHR readiness assessment tool and an article, "Think lean: Redesign workflow to adopt,"[277] that discusses lean management for workflow analysis. The fundamental components include:

- A statement that articulates goals and expected outcomes,
- Current process diagrams,
- A targeted group process for analyzing workflow maps, sharing knowledge and redesigning workflow and processes,
- Identification of methods to measure the impact of new workflows,
- Testing workflow redesign on a small scale,

- A process for continuous improvement, and
- Application of the process redesign approach to other areas.

Quality Improvement Organizations (QIOs)

Colorado Foundation for Medical Care (CFMC): CFMC worked with practice staff to improve identified processes. They started by observing and mapping the current state. When mapping a process, the focus was less on clinician workflow and more on the flow of the patient. Tools utilized included observations, interviews, process mapping and value-added time analysis. Value-added time analysis was used to evaluate practice efficiency by measuring four components of a patient visit—check-in, intake by a nurse or medical assistant, time with the provider and check out. The areas with the most time variance were targeted for improvement (e.g., they found that the time spent waiting for the physician in the exam room was highly variable). CFMC staff had difficulty transferring the skill of mapping to practice staff and this highlighted the need for a practice champion.

The next steps were to help practice staff develop and implement improvements. Unfortunately, CFMC staff noted that many of the practices did not permanently integrate improvements and often returned to old processes.

CFMC is currently working to improve communication between practices and patients, labs, and pharmacies. They are also helping practices to use data from their EHR systems for reporting. CFMC would like to develop a process map library—similar to a Craig's List. They would also like to teach practice teams to use observational tools and then have them conduct observations at another practice so the practice learns firsthand about processes.

Illinois Foundation for Quality Health Care (IFQHC): IFQHC has a Web page dedicated to EHR selection assistance and resources. The American Medical Association links to IFQHC resources including models, diagrams, and checklists for workflow assessment and redesign. These include assessments for front desk procedures, patient visit tasks for MAs, RNs, MDs, labs, referrals and check-out processes, prescription refills and phone calls. Several 'operational redesign' documents can be used to analyze patient flow, point of care documentation, in-office communication, document management, prescription refills or renewals and patient appointment scheduling.

MetaStar: Through their involvement in the CMS DOQ-IT project, particularly the 8th scope of work, MetaStar provided support to primary care physician practices that served a Medicare population in the adoption and use of EHRs. A total of 25 practices and approximately 95 sites participated in the project. They coached many of the practices, particularly during the phases of planning and selection of health IT. Additionally, they worked with the practices in process mapping. Practices needed a lot of coaching to grasp process mapping, but they found it very useful. When mapping processes, MetaStar teams typically started with a group of practice staff to draw the process on a laptop that was projected—a couple iterations were necessary to finalize the process map. Practices then, typically, followed the vendor's methodology for implementation. Vendors did not provide much support in workflow design or redesign and were more concerned about data flow. MetaStar learned from practices that their primary sources of information for health IT came from vendors or HIMSS.

State-Level Organizations and Associations

Massachusetts eHealth Collaborative (MAeHC): MAeHC conducted a demonstration program where EHR systems were successfully implemented in approximately 200 practices within 2 years. Three communities in Massachusetts participated in the project. Implementation was successful in both the willing and resistant practices. Approximately 60,000 records per month are reported to a central repository, so it appears the systems are being used although the data have not yet been analyzed. Implementation was a two-step process with the practice management system being implemented first. The EHR was customized at the practice level (e.g. templates) with a lot of hands-on personnel time working with the vendor and conducting workflow redesign and training.

The MAeHC conducted surveys both pre- and post-implementation. The pre-implementation survey measured attitudes, existence of health IT and other issues. The post-implementation survey addressed what was useful, what was good with training and consulting, how often the EHR was used, and use of functions such as templates, flow sheets, patient recalls, billing alerts, access to patient records before and after, etc. They will revisit the communities in a few years to conduct another survey evaluating the use of EHR, updates, and use of expanded functionality. The following papers highlight their experiences along with workflow issues:

- "Community-wide Implementation of Health Information Technology: The Massachusetts eHealth Collaborative Experience"[278]
    - Factors for large-scale EHR adoption include, "strong financial backing, intensive practice support, commitment to collective action, clear goals, leadership from the physician community, governmental support, and a community-based focus" (p. 136). Converting from paper to electronic records is a fundamental change and smaller practices may not be able to manage the change without assistance. Standards for representing data and vocabulary are inadequate.
- "A tale of two large community electronic health record extension projects"[279]
    - Lessons learned include: (1) work with the community by helping to set expectations, providing additional support, facilitating a learning community and knowing when to give up, (2) work with EHR vendors to create "scalable solutions" through standardization—which may involve new workflows for practices, (3) "focus on functional interoperability" (p. 354) through data exchange, and (4) remember that the ultimate goal is "improved public health, quality of care, and health system efficiency" (p. 355).
- "Engaging patients for health information exchange"[280]
    - Two lessons learned include: (1) the importance of "engaging the trust and willingness" of all stakeholders for sharing and exchanging medical records, and (2) sustainability depends on the "clinician's willingness to use the product" and "patient engagement" (p. 442).
- "Physician attitudes toward health information exchange: Results of a statewide survey"[281]

- A survey revealed the majority of physicians believed health information exchange (HIE) would have a positive effect on health care costs, quality, and time savings. Many physicians, however, were concerned about privacy and security. Both primary care providers and specialists had positive attitudes towards HIE. Advanced EHR users had a more positive attitude than those with no EHR. Those in medium-sized practices were more positive than those in larger or smaller practices.

Additionally, MAeHC, with other associations, published the Clinician's Guide to Electronic Prescribing.[273]

Michigan Improving Performance In Practice (IPIP): The Michigan Improving Performance In Practice (IPIP) focuses on the Wagner Chronic Care Model, which provides guidelines to improve chronic illness care. They also include the IPIP 'change package' to improve quality of care using coaches (http://www.ipipprogram.org/).

Michigan IPIP coaches are experts in process engineering/improvement and quality management from the manufacturing industry who volunteer their time to assist practices. Before beginning their work with practices, coaches are exposed to the clinical environment and trained in health care terminology and practices. When discovering how inefficient many of the practices were, they decided to focus first on providing resources to improve practice operations and finances before working on clinical aspects.

Coaches use various tools when assisting practices in workflow analysis and redesign including value stream mapping, process maps, plan-do-study-act methodology, and the Cost of Current Quality (COCQ) method. Coaches encountered a lack of 'readiness' for change, staff blaming each other for problems in their current processes, a lack of leadership (e.g., practice champion), a lack of understanding of the value of coaching, and lack of time for workflow analysis and redesign. Practices need to understand the benefits of coaching and coaches need to use language that practices will understand. Additionally, there needs to be an awareness of practice culture (e.g., interactions between physicians and other practice staff) to effectively analyze processes.

New York Primary Care Information Project (PCIP): The New York Primary Care Information Project (PCIP) has both EHR implementation and quality improvement (QI) teams. The implementation team conducts three to five visits at each practice for analyzing and redesigning workflow. There are 16 standard workflows developed by the vendor that are modified, as necessary, by the practices. The goal is to have each practice conduct workflow analysis on their own. PCIP will work with the practice to redesign processes that need improvement prior to EHR implementation. Workflow is often analyzed using Microsoft Visio®. Workflows analyzed include: telephone and e-mail encounters, patient check-in and check-out, document management, visits such as well child checks, lab tracking with and without lab interfaces, internal and external referrals, immunizations, prescription refills, billing and helpdesk. Test tracking is often evaluated later when the practice is live with the lab interface. Implementation occurs in two phases with the first being billing and appointment scheduling. The front office staff is then able to train the providers when the EHR goes live for the entire practice. The amount of time from signing the EHR contract to going live varies with a range of approximately 20-23 weeks.

For small practices, the QI team consists of five specialists—each with a case load of approximately 30 practices. PCIP focuses each specialist in a particular NYC borough so similar practices have the ability to network with one another. Each team consists of an EHR super-user and a billing/coding specialist. QI teams conduct 10 visits at each practice where they help them think through EHR issues pertinent to patient safety and quality. The patient-centered medical home provides a strategic framework to think through EHR usage. Practices are required to participate in quality improvement measures (the Department of Public Health focuses on 10 core areas for QI and 40 quality measures such as mental health). Practices are obligated to use the EHR fully and their usage is tracked. Data on utilization (e.g., the percent of visits using e-prescribing) and quality measures are automatically aggregated on a monthly basis and sent to a data warehouse. Practices are also able to run their own quality measures at the patient level. QI teams note that the main barrier to quality improvement is limited resources in time and finances. PCIP has observed the following workflow issues:

- The EHR selected for the PCIP project has approximately 30 templates and it is easy for practices to build their own.
- PCIP provides an online forum where practices are able to share information with each other.
- The barrier with billing and coding is that sites have additional data to enter into the system. The system will automatically perform billing calculations but needs the additional data to do so.
- Many providers do not know how to treat a small practice as a business—they do not understand the impact EHR has on billing, workflows, training, work hours, and other issues. Thus, providers need a starting point such as templates and best practice recommendations.
- It helps to transfer some of the provider responsibilities to nurses or medical assistants and incorporate this into standard workflows.
- Training must be done at the pace of the practice.
- They have a number of valuable references including the following:
- "Electronic Health Records for the Primary Care Provider."[282] This publication discusses improving workflow and care management processing through the use of EHRs including point-of-care reminders, benchmark reporting, population disease management and patient education. There are also discussions of the clinical function of EHRs, choosing vendors, and financial considerations.
    - Lessons learned include: (1) "establish a good working relationship with your EHR vendor," (2) "plan adequately for implementation" such as taking advantage of group purchases, being realistic about timeframes and costs, ensuring adequate support, identifying practice champions, conducting readiness assessments, thinking through workflow changes, and evaluating staff computer proficiency, (3) "minimize the period during with both paper and electronic systems are used concurrently," and (4) "commit to ongoing training to address underutilized aspects of the system" (p. 5).
- The PCIP booklet, "What Do Electronic Health Records Mean for Our Practice," discusses the challenges of paper-based systems and the benefits of EHRs. Efficiencies added through the use of EHRs include practice management, chart management, communication, reduced medical errors and others. It also discusses the workflow implications for various staff members (providers, nurses, MAs, front office staff, back office staff and billing staff) such as the use of templates, electronic

scheduling and prescribing, remote access, call logs, patient check-in process, accuracy of billing and claims and many other features.

- PCIP provides an Electronic Health Records Readiness Worksheet and a Small Practice Economics Information and Worksheet that discusses the return on investment of EHRs.

Wisconsin Medical Society (WMS): The Quality and Efficiency team at WMS has historically done work in advocacy but is now growing in research. They conduct teleconferences on coding and compliance and have created "hubs" of practices to share experiences and information received from vendors. WMS is participating in health IT and statewide health information exchange activities with the State of Wisconsin Department of Health Services.

With regards to workflow, WMS notes the following:

- The billing system is just as important as the clinical system and vendors need to understand the billing system and requirements for compliance.
- During implementation, you must have buy-in from all the players in the organization including regulatory compliance officers, coding and accounting in addition to practice staff.
- Length of training is very important and there may be issues with trainers who have no clinical background.
- It is important for a practice to understand themselves in terms of physical environment, size of practices, finances and workflow before shopping for an EHR.
- Methods for workflow analysis include a fill-in-the-blank text method or mapping processes with Microsoft Visio®. It is also important to think about workflow from a hardware perspective.
- Practices often do not understand that workflow is crucial to EHR implementation and often need a coach to encourage them to follow through with workflow analysis.

Non-Health Care Organizations and Associations

American Society for Quality (ASQ): ASQ has tools and resources within the Knowledge Center Web page. Tools include process analysis methods such as flow charting, check sheets, control charts, and failure modes and effects analysis (FMEA) plus many others. Each tool includes a description of when to use it, a procedure and examples. Additionally, ASQ has a Web page dedicated to quality in health care with much of the information available through purchase or membership.

Carnegie Mellon Center for Computational Analysis of Social and Organizational Systems (CASOS): CASOS research involves the development of metrics, theories, computer simulations, toolkits, and new data analysis techniques and is combined with an understanding of the underlying cognitive, social, political, business and policy issues.
CASOS offers numerous open source tools that may be used for workflow analysis.

Institute of Industrial Engineers (IIE) and the Society for Health Systems (SHS): SHS publishes conference proceedings, articles and papers which address many topics including methods in analyzing and improving workflow in health care. Examples include:

- "Value Stream Mapping Got You Down? The Problem May Not Be You." that provides a brief discussion of when value stream mapping may not be an appropriate tool.
- There are numerous conference proceedings discussing Lean Six Sigma publications on a variety of topics and applications such as, "Improve Outpatient Clinic Access and Service with Lean Six Sigma" that evaluates appointment wait times and cycles and "Engaging Staff in Lean Improvements for Patient Care Settings"—both papers require membership for viewing.

Other Organizations

Surescripts: Surescripts certifies all their application vendors for three sevices: prescription benefit, medication history, and prescription routing. They provide a team of experts that work with the vendors to develop tools and resources for their customers to make transitions as smooth as possible. Surescripts recommends http://getrxconnected.org as a resource for e-prescribing and using the *Clinician's Guide to Electronic Prescribing*[273] as a resource for getting started with e-prescribing. They also provide a list of case studies of e-prescribing success stories.
The drivers of success for EHR implementation, according to Surescripts, include having buy-in throughout the practice, the presence of a champion, having a designated person responsible for workflow issues and having a vision and strong belief that the health IT will improve quality, safety and communication. Common workflow issues encountered in e-prescribing include the management of prescription renewals, prescriptions not being available at a pharmacy when a patient has been told otherwise and personnel training in health IT functionality.

Upstate Neurology Consultants, LLP: Upstate Neurology Consultants, LLP is a single specialty practice with two locations, seven physicians, one physician assistant, and 20 employees. Upstate Neurology had three reasons for implementing their EHR: (1) in a period of declining reimbursements for health care, they needed to find a means to reduce costs, (2) health IT was becoming an item of interest and the underlying IT backbone was tested and reliable, and (3) they came across a product that addressed their issues including improving practice management, allowing scanning of business and clinical records, and others. Their EHR record went live in 2005 and they now have 4 years of electronic patient data.

Upstate Neurology observed there was very little information available regarding EHR implementation and workflow analysis when they were going through the implementation process. Before implementing their EHR, a consensus was reached amongst all the providers to use the same workflow methods and approaches—no variations were accepted. Every patient flow process was identified and broken down to maximize efficiency and ensure successful integration with the EHR. When rolling out their EHR, processes were tested to ensure efficiency. Workflow issues that surfaced were adapted and adjusted to make efficient use of time. They had explored conducting the workflow analysis in-house or through a consulting firm and decided on in-house analysis where each member involved in a particular workflow process was included in the analysis. Scribes and charting were used to record and analyze workflow discussions. Methods were then tested with various groups to get reactions. During the rollout phase, issues were found with the software that was not intuitive to their practice workflow. They compiled their list of software improvements and submitted to the vendor—the vendor was very responsive and they were generally able to get what they wanted; although not everything. Upstate Neurology identified their lessons learned for health IT implementation processes:

- Make all processes efficient. Recognize that any unaddressed broken process would be magnified with the implementation of EHR.
- Obtain uniform backing from all the physicians in following processes once established.
- Involve all staff in the process analysis.
- Allow time to test, make and correct mistakes, and analyze workflow. Do not rush the process.

Upstate Neurology noted that their EHR impacted workflow by helping and expediting communication across the practice. It also facilitated the flow of information between practices and outside institutions. They have also been able to use their EHR to mine data on clinical information to help physicians in determining treatments and to help improve patient care processes.

Findings: Highlighted Workflow Issues from Organization/Association Review

Workflow issues found in the organization/association review of the environmental scan were categorized by their relation to *tasks*, *time and cost*, and *other*. Categories were determined based on the workflow issue that was discussed and are not mutually exclusive.

Table 11: Workflow issues found in the environmental scan

Workflow category	Workflow issue
Tasks	Role responsibility changes (e.g., physicians now handling activities that staff previously had previously)
	Ability to see more patients
	Changes in the number of calls returned to pharmacies
	Multiple requests for renewal
	Pharmacies not checking the e-prescribing system
	Pharmacies sending renewal requests in multiple manners causing confusion in the practice
Time and Cost	Additional time to complete new tasks
	Time spent on the phone following up pharmacies about medications
	Delays in locating paper records or outside lab results
	Costs associated with transcription
	Reduced time in faxing prescriptions
Other	Finding and removing bottlenecks in workflow processes
	Improved communication across the practice
	Facilitated flow of information between practices and outside institutions
	Patients refusing e-prescribing
	Prescription not available at a pharmacy when a patient was told otherwise

Findings: Highlighted Workflow Guidance from Organization/Association Review

Workflow advice found in the organization/association review of the environmental scan was identified and categorized by its relation to *infrastructure, stakeholders, vendor advice, training, tools for analysis, types of workflow, workflow analysis, workflow enhancement,* and *general*. Categories were determined based on the guidance content.

Table 12: Workflow guidance found in the environmental scan

Guidance category	Specific guidance
Infrastructure	Interfaces may be necessary for exchanging data applications.
	Small or rural practices may encounter challenges (e.g., broadband connectivity and access to skilled professionals).
	Ensure tools are in place before training and workflow redesign by reviewing items such as internet connectivity, network infrastructure and hardware.
	Use consultants to determine the necessary infrastructure for implementing health IT.
	Set up the exam room so the provider can face both the patient and computer.
Stakeholders	Involve many users when addressing workflow (e.g., physicians, practice managers, billers, triage nurses, receptionists, and all members of the practice team).
	Obtain buy-in from all the players in the organization.
	Obtain agreement from all physicians to follow processes once established.
	Stakeholder trust and willingness is important for sharing and exchanging medical records.[280]
Vendor advice	Tools for workflow analysis and redesign can vary depending on who is responsible for health IT implementation, training, and support.
	Vendors may not provide much support in workflow design or redesign.
	EHR vendors rarely support high-level functionalities such as reporting patient safety measures, e-prescribing, electronic test results, alerts, and others.
	Vendors need to understand the billing system and requirements for compliance.
Training	Invest in training upfront to avoid costly setbacks after the health IT is implemented.
	Training must be done at the pace of the practice.
	There may be issues with trainers who have no clinical background.
	Visuals and applied learning concepts are important during training.
Tools for analysis	Use value-added time analysis to evaluate practice efficiency.
	Practices need a lot of coaching to grasp process mapping.
	Methods for workflow analysis may include a fill-in-the-blank text method or using Microsoft Visio®.
	Practices may not respond to using formal tools for workflow analysis. They will likely respond to simple, step-by-step instructions.
	When mapping a process, focus less on clinician workflow and more on the flow of the patient.
Types of workflow	Document workflows within the practice such as appointment scheduling, unscheduled visits, and patient visit activities.
	Consider workflows for how the office will function during unanticipated system downtime.
	Understand office functionality and address any redesign issues.
	Fit the practice to the EHR through a detailed analysis of how tasks are performed. Reengineer/redesign the practice to complement the EHR.
	Transfer some of the provider responsibilities to nurses or medical assistants and incorporate into standard workflows.
	Smaller practices may not be able to manage converting from paper to electronic records without assistance.[278]
	Understand the practice in terms of physical environment, size, finances and workflow before selecting an EHR.
	Think about workflow from a hardware perspective.
Workflow analysis	Workarounds may be implemented and integrated into workflow if a practice rushes EHR implementation.
	Identify and test workflows before implementing an EHR system to mitigate problems.[31]
	Basic workflow redesign principles include simplicity, accessibility for patients, safety, thorough documentation and task delegation.[31]
	Practices that conduct workflow analysis prior to health IT implementation are usually successful.
	Be aware of practice culture (e.g., interactions between physicians and other practice staff) in order to effectively analyze processes.
	Practices often need a coach to encourage them to follow through with workflow analysis.
	Unaddressed, broken processes will be magnified with the implementation of EHR. Allow the necessary conversations for making all processes efficient.
	Do not rush the process. Allow time to test, correct mistakes, and analyze workflow.
Workflow	Implementing kiosks for patients to access.

Guidance category	Specific guidance
enhancement	Provide the ability to fax and print patient information in the exam room.
	Implement electronic messaging systems to enhance flow of patient information.
	Translating workflow from paper to the computer may be subject to 'rebuilding'.
	Post-workflow analysis can be used to optimize workflow.
General guidance	Providers need a starting point such as templates and best practice recommendations.
	Show that health IT can improve workflow.
	Small practices would benefit from additional resources during the transition.
	Implementing in two phases, with the first being billing and appointment scheduling, allows front office staff the ability to train providers when the EHR goes live for the entire practice.

Links Identified for Toolkit

The goal of the Links Web page in the toolkit is to help the toolkit end users identify additional resources for their concerns regarding implementation of health IT. In Table 13 is a list of some links included in the toolkit.

Table 13: Useful Web links

Name of Source	Link
DOQ-IT University	DOQ-IT University: http://www.masspro.org/HIT/DOQU/index.php
American Academy of Family Physicians (AAFP): The Center for Health IT	AAFP Center for Health IT: http://www.centerforhit.org/online/chit/home.html
American College of Physicians (ACP): Health Information Technology	ACP Health IT: http://www.acponline.org/running_practice/technology/ Implementation: http://www.acponline.org/running_practice/technology/ehr/roadmap/ehr.htm#inst Patient Centered Medical Home: http://www.acponline.org/running_practice/pcmh/help.htm
Institute for Healthcare Improvement (IHI)	IHI: http://www.ihi.org/ihi Improve workflow and remove waste: http://www.ihi.org/IHI/Topics/OfficePractices/Access/Changes/ImproveWorkFlowandRemoveWaste.htm
Medical Group Management Association (MGMA)	MGMA: http://www.mgma.com/ EHR and Meaningful Use: http://www.mgma.com/solutions/landing.aspx?cid=16706&id1=16690&id2=17076&id3=16998&id4l=17002&id4r=17006&id5l=17010&id5r=16996&id6=17008
Institute of Industrial Engineers - Society for Health Systems (SHS)	SHS: http://www.iienet2.org/SHS/
HIMSS Davies awards	HIMSS Davies Awards: http://www.himss.org/davies/pastRecipients_ambulatory.asp
Office of the National Coordinator for Health Information Technology (ONC)	ONC: http://healthit.hhs.gov
Healthcare Technical Group of the Human Factors and Ergonomics Society (HFES)	Healthcare TG: http://hctg.wordpress.com/
American Medical Association	e-Prescribing Learning Center: http://www.ama-assn.org/ama/pub/eprescribing/home.shtml Putting Health Information Technology (Health IT) into Practice: http://www.ama-assn.org/ama/pub/physician-resources/solutions-managing-your-practice/health-information-technology/putting-hit-practice.shtml Physician Resources—Tools: http://www.ama-assn.org/ama/no-index/physician-resources/16878.shtml
ACP Internist	ACP internist: http://www.acpinternist.org/archives/2008/02/pmctips.htm

User Stories

Methods

Identification of user stories. The objective in identifying user stories was to find published stories of workflow issues encountered before, during or after health IT implementation in small and medium-sized ambulatory care clinics. Through these user stories, toolkit users should be able to identify ambulatory clinics similar to themselves with the goal that they be able to anticipate workflow issues before, during or after health IT implementation.

User stories were identified through:

1. Literature search: Gray literature identified in the literature search that addressed user experiences of health IT, workflow, and ambulatory care was reviewed for inclusion as user stories. See the Chapter 2 for a description of the literature search methods.
2. Focused Web searches: User stories were identified through focused Web searches using key terms identified in the literature search methodology. See the Chapter 2 to review the key terms.
3. Request for Information: Several responses to the Request for Information provided sufficient information for inclusion as user stories.

All identified user stories were reviewed and included for use in the toolkit if they were applicable to small and medium-sized ambulatory care clinics and involved a discussion of health IT and workflow. User story references can be found in Appendix D.

Characterization of user stories. A total of 37 user stories were identified for inclusion; 24 from the environmental scan (including 3 from the RFI) and 13 from the literature review. Each user story was evaluated for the following components:

- Source: Who provided the information and how the information was gathered
- Summary: A detailed summary of user story
- Objective: A concise summary of user story
- Setting: type of clinic(s), health care system affiliation, size (numbers of specific staff and visits), geography (urban, suburban, rural), contributors of story information, context
- Type of health IT being studied and its functions
- Workflow issues and results: identify workflow issues, how workflow data was collected, workflow results
- Tools: tools used to analyze workflow
- Contact information: user story URL.

All information was recorded in a database for use in the toolkit according to the data entry instructions prepared for the literature review summaries (see the literature search methods for instructions). The synopses that follow are descriptions of the 24 user stories identified in the environmental scan.

User Story Synopses

Practice Characteristics. Of the 24 user stories identified in the environmental scan 14 were about/regarding primary care clinics (general care, pediatrics, family medicine, internal medicine),[283-296]4 were about specialty clinics (ambulatory chronic disease care, neurology, cardiac rehabilitation, diabetes and maternity clinics)[297-300] and 3 were about both.[301-303] Nearly all of the clinics were affiliated with a system.[283, 285, 287, 288, 290-303] Few of the user stories provided information on the number of providers, staff, and patient visits. Of those that provided information on the number of providers and staff, the majority had 20 or less.[283-286, 289, 292, 296, 299, 300] The number of visits varied from 11,000 to nearly 100,000. The majority of the clinics were either urban or suburban.[283-285, 287-296, 298-303] Only one identified rural clinics amongst its urban and suburban clinics.[298] Study participants consisted primarily of clinical and administrative staff with a few user stories specifically identifying primary care physicians,[290, 294] nurse practitioners,[299] nurses,[297-299, 301, 303] paramedics,[297] or social workers.[298] Some of the user stories noted that they already had practice management systems,[283, 284, 286, 287, 289-291, 300] including billing and scheduling, in place during the time they were implementing their health IT. The majority of the health IT applications discussed were EHRs or EMRs;[283-289, 291-293, 295, 296, 298-300, 302] a few solely discussed disease registries,[290, 303] clinical decision support,[297] e-prescribing,[301] and one referenced a "paper-based" information system.[294]

Workflow issues identified in user stories. Experiences with the health IT applications represent both pre-, intra- and post-health IT implementation activities or outcomes and are positive, negative or neutral. All of the experiences demonstrate some impact on workflow. We grouped the results of the user stories into six major categories:

- *Reminders, alerts, and reports* that, when provided, increased efficiency and improved workflow.
- *Administrative and clinical workflow, and work/job design* having positive and negative impacts on workflow and job content.
- *Patient-provider consequences* of the health IT system that affected workflow.
- *Interface design* that affected job content and workflow.
- *System integration* that, in all cases, positively affected workflow.
- *Planning activities* and their impact on workflow.

Within each of the categories we identify more specific workflow issues or consequences associated with a particular health IT application.

Reminders, alerts and reports. Because of the automatic nature of health IT-driven reminders, alerts and reports, the user stories that discuss these all reflect positive consequences on both the work and workflow of the providers and patients, and ultimately the quality of care and services rendered. The reminders and alerts included notices to patients in need of screening procedures, preventive care, vaccinations, and other clinical services. Physicians received similar notices (e.g., preventive care reminders) at the point of care.[284, 286, 289, 290, 292, 294, 302, 303]

Administrative and clinical work(flow) and work/job design. Consequences reported post-implementation on administrative workflow varied by the type of health IT. Two user stories on integrated EMR/practice management systems[291, 292] and a registry[303] reported positive results that included greater efficiency in terms of the work performed and improved information access that promoted more efficient workflow (e.g., decreasing the number of steps associated with refilling prescriptions from11 to 2 steps). The most frequently reported positive experiences from the other stories included improved information (and “chart”) availability such as easier access to patient histories, current medications, and lab results,[284-286, 289, 296] as well as better internal communication,[284] and a streamlined workflow that had a positive impact on increasing patient volume and decreasing patient waiting time.[287] One user story describes utilizing the EMR for process improvement activities that addressed medication refilling, lab result reporting and phone call response processes.[286] All of the other consequences reported that had an impact on workflow demonstrated: shifts in responsibilities that most often adversely affected the workload of the providers because tasks shifted to them[284-286, 289, 299, 300] and variations in clinical practice (and user perceptions) that made streamlining and standardization of clinical tasks difficult.[284, 299] Four user stories note the increase in work associated with scanning documents and reports from patients’ records pre-implementation and paperwork received from external sources post-implementation.[284, 285, 289, 298] One user story reported initial delays in patient waiting time immediately post-implementation that ultimately resolved.[284]

The use of vendor services was discussed in two of the user stories. An organization that implemented an integrated EMR/practice management system recognized the benefit of receiving regular coding and billing updates that enhanced the billing process and practice cash flow.[291] Another user story in which an EHR was implemented discussed the lack of support the vendor provided. Thus the EHR support function fell to the practice.[289]

Patient-provider consequences. The provider-patient interaction was affected in two very different ways. Health IT applications (in these instances EMRs and EHRs) offered tools for patient education and information gathering directly from the patient that preceded and then complemented the care provided.[289, 299, 303] Additionally, these systems provided a means of communicating electronically between the provider and patient that positively affected workflow. On the other hand, some providers felt the health IT applications interfered with their patient interaction and workflow, at least in part due to the physical placement of the system.[284, 285]

Interface design. When user stories discussed a less-than-optimal interface it was at least partially due to poor planning for the implementation, vendor restrictions, and/or a lack of sufficient understanding of workflow and information capture (converting paper documents to their electronic equivalent) pre-implementation.[285, 296, 298-300] Customized templates that captured direct visit-related information and offered links to internal and external resources were generally regarded as having a positive impact on workflow.[283, 289, 292, 299] Neutral comments concerning templates reflected provider-dependent use[299] and the need to re-learn work cues based on system use.[286] Charting by exception was effective when physicians’ clinical workflows could be documented.[292] Patient portals providing access to electronic patient records[292, 299] were generally viewed positively but responses varied by patient.

System(s) integration. Every user story that discussed integration of the system within their practice or between their practice and another practice reported positive impacts on workflow.[283, 285, 287, 289-293] Integration included:

- A joint clinical/practice management system that eliminated duplicate data entry in the two systems and also integrated the previous stand-alone systems in pharmacy and laboratory,[291, 293]
- Reports of patient test and procedure results regardless of a patient’s status as an inpatient or ambulatory,

- Collection and automatic assignment of external documents by the health IT system to the respective patient or clinical service (e.g., external laboratory reporting, automatic scanning and assignment of faxes between patients and their associated orders),[287, 291]
- Joint communication, order processing, results reporting and scheduling systems,
- E-prescribing capabilities, and
- Links to other external software (e.g., e-mail) that in turn facilitated communication with other providers.[292]

Planning activities. Workflow-related planning activities were discussed in a limited number of user stories. Four of the user stories discussed the need to document and understand workflow pre-implementation, with one of them[300] indicating insufficient attention to this activity. The other three stories[293, 301, 303] offered positive experience from the effort. Stakeholder involvement was deemed critical to the success of the implementation[288, 303] and stakeholder acceptance of the system was credited to the workflow efforts undertaken.[302]

Tools identified in user stories to analyze workflow. Workflow issues presented in the user stories were collected using a variety of tools (see Table 12).

Table 14: Tools identified in the user stories

Tools	Workflow information collected
Focus groups[290, 298]	Feedback on health IT, in general[290, 298] Feedback on user interface[298] How tasks are performed[298]
Usability[290]	Assessment of user interface[290]
Observation[283, 290, 295, 299, 300, 303]	How tasks are performed[290, 300] Pre-implementation state[283] Information flow[300] Duplicated tasks[300] Nonintegration of existing systems[300] Type and format of information collected[299, 300] Patient handoff processes[300] Nonstandardization of work processes[299] Inflexibility of system[295, 299] Time to complete tasks[299, 303] How system used[299] Inter-provider communication[295] System use[295]
Interview[287, 293, 295, 299, 301]	User feedback on system[293] How tasks are performed[287, 299, 301] Who performs what tasks[301] Steps in process[287] Processing time[287] User workload[287] Integration of systems[287] Type and format of information[299] Reasons for poor user satisfaction[295]
Flowchart, process map, cross-functional flowchart, activity diagram[284, 288, 293, 295, 298, 300, 301, 303]	Workflow ("reality state")[293, 295, 300, 303] Pre-implementation workflow[284] Pre- and (planned) post-implementation workflow[288]
Gantt chart[288]	Project management[288]
Checklist[283]	System configuration requirements[283]
Lean[288]	Present and future workflows[288]
Questionnaire/survey[294, 295, 297]	Acceptance[297] Attitude toward health IT[297] User satisfaction with health IT[292, 294]

Using health IT as a tool. The user stories primarily reported using health IT to enhance or assess workflow for reminders and/or alerts, quality reporting, and to facilitate process improvement efforts.

Reminders and alerts for:

- Physician Quality Reporting Initiative (PQRI)[290]
- Screening reminders related to pay-for-performance measures[303]
- Preventive care, wellness, and/or vaccination reminders[283, 286, 289, 292]
- Allergy or lab abnormality alerts[292]
- At-risk patients overdue for mammography screening, or other patient services[284]
- Clinical guideline adherence[302]
- Diabetic management coordination[303]
- *Reports or reporting for:*
- Patient education (e.g., demonstration of the impact of lowering blood pressure on cardiac risk)[289]
- Disease management reports related to pay-for-performance measures[287]
- Graphical display of measures for patient education and physician use[299]
- Adherence to clinical guidelines[302]
- Billing data sets that eliminate the need for medical abstractors[302]
- Physician prompting to complete screening and prevention measures and appropriately manage disease[294]
- Patient lab results[292]
- *Process improvement activities:*
- Process improvement for prescription refills and scheduling[286]
- Tracking process inefficiencies for prescription refills and lab results[287]

Tools

The tools found in the toolkit include instruments, methods, and strategies used to (1) collect information on, depict, and understand workflow; (2) inform workflow issues being addressed; and (3) recognize how the impact of implementation and use of health IT affects workflow. There are many tools that can be appropriately used within the domain of health care workflow (re)design. The intent of the tools section of the toolkit is to provide individuals relevant, user-friendly, useful information on each tool.

Methods

We defined a tool (that would be included in this toolkit) as any instrument, method, or strategy employed to perform, inform, or assist workflow analysis and redesign at any point in the selection, implementation, and/or use of health IT. A tool can be used in clinical and/or administrative applications. To meet the needs of users, we identified other similar human factors and ergonomics (HFE) toolkits against which to benchmark (e.g., FAA - https://www2.hf.faa.gov/workbenchtools/).

Identification and characterization of tools. Tool identification began with a focused Web search using internet search engines. We initially used keywords such as "workflow tools," “process analysis,” and “health information technology tools” to identify specific tools or sources providing information on tools. We also utilized a free online keyword suggestion tool (http://freekeywords.wordtracker.com/) to ensure that we searched as many keywords related to our definition of a tool as possible. Many of the pertinent sources identified offered links to other sources providing additional valuable information on either tools or workflow in health care. In order to ensure completeness of the tools compendium and their specified fields of information, the search for tools expanded to include the following:

1. Books: Books reviewed were primarily from the human factors engineering domain. We searched the Books in Print database using the workflow and key ambulatory care terms identified in the literature search. Nearly 400 books were reduced to 72 by excluding those that did not address workflow tools in the title or synopsis. The list was further refined to include 40 books. Additionally, books were identified through a nomination process by team members, TEP members and an Improving Performance In Practice (IPIP) group in Michigan on key workflow topics. The final list of books identified many new tools and content in terms of the quality and quantity of information. Several of these books are included in references for specific tools as suggested readings because they contain more in-depth content.
2. Request for Information (RFI): A number of responses to the RFI published on the Federal Register provided tool information or examples of tools.
3. Environmental Scan: We examined gray literature resulting from the structured literature search for workflow tools used. Organizations and associations with health IT initiatives were also reviewed for tools they recommend or report on to assess workflow. Additionally, nonindexed conference proceedings from the Society for Health Systems (SHS) and Health Information and Management Systems Society (HIMSS) and the digital archives for Patient Safety and Quality Healthcare (PSQH) were reviewed.
4. Literature search: Workflow tools discussed in the peer-reviewed papers included in the literature review identified other tools or examples of tools used.

We selected categories of information that would be helpful for users and guide them in their understanding and appropriate use of each tool. The categories of information we chose to collect for each tool include:

- The name of the tool (and acronym if it has one),
- Other names the tool is known by (“AKA”),
- A description of the tool,
- When or in what situation the tool could be used,
- The procedure for using the tool,
- Resources needed to use the tool (including technical expertise and supplies),
- Ddvantages and disadvantages of the tool,
- References (e.g., books, Web sites) maintained in an EndNote® database that provided any technical or educational information on the tool,
- Examples of the tool used in a health care setting identified in case studies and research projects or pdf copies of tools collected from organizations during the life of the contract, and

- Other resources incorporated in the toolkit from project-related activities (e.g., the environmental scan, RFI and Web searches).

We subsequently entered all relevant information on each tool into these categories in a Microsoft® Office Word 2003 table—a tool compendium.

The tool compendium was continuously updated over the course of the project. New tools or additional tool information emerged from the user stories and literature review database. Any tool reported from either of these sources was "double-checked" to ensure its inclusion in the tools database. If a new tool was identified through this process, it was added to the database. If a synonym for a tool was identified, it was added as an "AKA" in the respective database field. Related user stories and scientific papers were also verified for inclusion in the respective output for a tool. The result of these efforts is a compilation of about 100 instruments, methods, and strategies that can be used to perform and inform workflow analysis and redesign in the context of health IT implementation.

In many instances, information on a tool was collected from multiple sources, and thus many tools had several complementary definitions, procedures and other information. For example, as the tool compendium approached completion, information on flowcharts came from 16 different sources, offered nine complementary descriptions, and seven similar procedures. The final "toolkit" version of the tool description and/or its procedure integrates the information obtained from the multiple sources so that there is one complete definition and procedure for each tool. Small edits and additions were often made to the information captured in order to make it more user-friendly and understandable. During this refinement process some tools were eliminated because there was not enough useful information or they did not correspond with the types of tools we chose to include in the toolkit. The final tool compendium containing all tools and their respective information is found in Appendix F.

Categorization of tools. We determined that, much like the FAA HFE internet toolkit (https://www2.hf.faa.gov/workbenchtools/), a guided search for tools would offer a means of both educating and assisting users in their search for appropriate tools that could be used to meet their needs. Therefore, once a significant number of the tools were collected, we identified categories of tools. Categories represented common uses of the tools and came from various HFE references including Human Factors Methods: A Practical Guide for Engineering and Design.[304] We created a spreadsheet in Microsoft® Office Excel 2003 where tools were listed in the first column and the category listed as a column heading on the subsequent 12 columns. Assignment of tools to a category(ies) was an iterative process. Two team members worked on the assignment independently. When they disagreed on category assignment, discussion ensued until an agreement was reached. Categories are not mutually exclusive and, thus, a tool may appear in more than one category. Table 15 describes the 12 tool categories.

Table 15: Tool categories

Tool category	Tool category description
Data collection	These tools provide a means of gathering information related to a task or issue.
Data display/organization	These tools provide standard and readily comprehensible means of visually presenting data.
Idea creation	These tools offer varying formats for identifying new or different ideas.
Problem solving	These tools provide team members organized, established methods for better understanding and then solving problems.
Process improvement	These tools offer means of scrutinizing and improving processes to enhance output/outcomes.
Process mapping	These tools offer visual means of conveying the flow and interaction of information, work and processes.
Project planning/management	These tools furnish project managers, participants, and upper management a means of understanding tasks associated with a project as well as progress associated with the project's timeline.
Risk assessment	These tools are used for identifying and/or analyzing known or anticipated problems associated with specific processes.
Statistical	Statistical tools attempt to provide meaning to a larger group of data by conveying relationships between the data and/or summarizing them.
Task analysis	These tools provide a variety of methods that can be used to better understand tasks, generally those associated with work processes.
Usability	Usability evaluations are conducted to obtain user input and/or identify design issues related to aspects of a system (e.g., a specific health IT system) such as appearance, function and navigation.
Health IT	Health IT applications can provide tools by reporting data or identifying poor performance (e.g., through exception reporting). These data can be used to better understand known or potential workflow issues.

The tools and their respective category(ies) are listed in Table 16.

Table 16: List of tools by category

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
5S					x							
5W2H				x								
Affinity Diagrams		X										
Allocation of Function Analysis							X					
AΔT					x							
Balanced Scorecard	x	X					X					
Bench-marking			x		x							
Benefits and Barriers Exercise					x		X					
Box and Whisker Plot		X										
Brainwriting			x									
Cause-and-Effect Diagram		X		x				x				
Checklist	x	X										
Cognitive Task Analysis	x										x	
Cognitive	x									x		

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Walkthrough												
Comms Usage Diagram (CUD)	x				x		X					
Contingency Diagram			x	x				x				
Cost-of-Poor-Quality Analysis					x							
Critical Decision Method (CDM)	x											
Critical Incident				x								
Critical Incident Technique (CIT)	x											
Critical Path Method							X					
Critical-to-Quality Analysis				x								
Cross-functional Flowchart		X				x						
Cycle Time Chart		X				x						
Decision Action Diagrams (DAD)		X				x						
Decision Matrix		X										

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Decision Tree		X				x						
Event Tree Analysis (ETA)		X						x				
Failure Modes and Effects Analysis (FMEA)								x				
Fault Tree Analysis (FTA)		X						x				
Flowchart		X				x						
Focus Group	x		x	x								
Force-field Analysis		X		x								
Gantt Charts		X					X					
Gap Analysis				x	x							
Goals, Operators, Methods, and Selection Rules (GOMS)					x						x	
Groupware Task Analysis (GTA)				x	x						x	
Heuristic Evaluation										x		

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Hierarchical Task Analysis (HTA)					x	x					x	
Histogram		X										
Interview	x											
Kano Analysis		X										
Kepner-Tregoe Matrix	x			x				x				
Lean					x							
Lean Six Sigma					x							
List Reduction				x								
Log	x											
Matrix Diagram		X					X					
Metrics Evaluation					x							
Multi-vari Chart		X							x			
Multivoting				x								
Murphy Diagrams				x				x				
NASA Task Load Index (NASA TLX)	x										x	

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Needs Assessment			x	x								
Nominal Group Technique (NGT)			x									
Observation	x											
Operation Sequence Diagrams (OSD)		x						x				
Pareto Chart		x										
Plan–Do–Check–Act (PDCA) Cycle					x							
Political, Economic, Social, and Technological Forces (PEST) Analysis				x				x				
Potential Problem Analysis (PPA)								x				
Process Decision Program Chart (PDPC)								x				
Process Scorecard	x										x	

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Program Evaluation and Review Technique (PERT) Charts							x					
Questionnaire for User Interface Satisfaction (QUIS)	x											
Radar Chart		x										
Regression Analysis									x			
Relations Diagram		x					x					
Requirements and Measures Tree		x										
Requirements Table		x										
Root Cause Analysis								x				
Scatter Diagram		x										
Simulation										x	x	
Simulation Modeling				x					x			
SIPOC (Supplier, Inputs, Process,		x										

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Outputs, Customer)												
Six Sigma					x							
SMART Matrix							x					
Social Network Analysis (SNA)		x										
Statistical Process Control (SPC)		x							x			
Strategic Planning							x					
Stratification		x										
Strength, Weakness, Opportunities, and Threats (SWOT) Analysis					x		x					
Survey	x											
Tabular Task Analysis (TTA)											x	
Task Decomposition											x	
Time and Motion Study	x											
Time Value Map		x										

	Data Collection	Data Display/ Organi-zation	Idea Creation	Problem Solving	Process Improvement	Process Mapping	Project Planning/ Management	Risk Assessment	Statistical	Usability	Task Analysis	Health IT
Top-down Flowchart		x				x						
Tree Diagram		x										
Trend Analysis		x										
Usability Evaluation										x		
Use Case				x		x						
Value Stream Mapping		x				x						
Value-added Analysis		x			x	x					x	
Verbal Protocol Analysis (VPA)	x										x	
Workflow Diagram		x				x						
Workflow Editor/Engine												
Workload Profile Technique	x										x	

Basic Tools

The team recognized that many of the toolkit users would not have the time or skills to become familiar with all the tools identified. Therefore, we selected a small number of “basic tools.” We agreed that by using at least one basic tool appropriately, an individual would gain a better understanding of the impact of the health IT on workflow. The “basic tools” were chosen based on their relative ease of use, value for accurately assessing and capturing workflow, and the frequency with which they were reported in the user stories or literature review papers. Those chosen include:

- Check list
- Flowchart
- Interview
- Observation
- Risk assessment
- Benchmarking
- Usability
- Health IT

The output for each of these tools is “rich” in pertinent information and examples. Links between the various databases in the toolkit are provided to offer users immediate access to others’ experiences and concrete examples of their work. For example, the toolkit describes instances in which flowcharts were effectively used and reported in user stories and literature review papers. Examples (e.g., PDFs) of, in this case, flowcharts are also available.
We understand how use of the toolkit could influence the success of health IT implementation through workflow analysis and redesign. We, therefore, recognize the need to provide relevant, user-friendly information to users of the toolkit.

Conclusion

The environmental scan produced many user stories and tools relevant to workflow analysis and redesign for health IT implementation in ambulatory care practices. A unifying theme amongst all references is that practices must have a comprehensive understanding of how clinical and administrative work is performed in their environment and how these processes might change with the introduction of health IT. All relevant information from the environmental scan and literature review are synthesized and displayed in a toolkit to assist practices in their workflow analysis and redesign efforts. This information is presented in a user friendly and searchable format. Usability evaluations conducted with identified user groups from small and medium-sized practices and intermediaries will ensure relevancy and ease.

Chapter 4. Assessment of the State of the Field

In 2006, Chaudhry et al. systematically reviewed the impact of health IT on quality, efficiency, and costs of health care.[44] They found that high-quality research was performed at four benchmark institutions with internally developed health IT, describing six studies on the impact of health IT on provider time and seven studies on how health IT was used as a tool to change practice. Their overall conclusions on these two themes were that health IT had mixed impact on provider time and can be a positive vehicle for practice change. As for most other studies—those performed at nonbenchmark institutions that used commercial health IT systems—Chaudhry et al. noted that study quality was poor and that "published evidence of the information needed to make informed decisions about acquiring and implementing health IT in community settings is nearly nonexistent. For example, potentially important evidence related to initial capital costs, *effect on provider productivity*, resources required for staff training (such as time and skills), and *workflow redesign* is difficult to locate in the peer-reviewed literature" (p. E-18, emphasis added).[44]

In 2010, evidence about the impact of health IT on workflow is still lacking. The reasons for this are multi-factorial, relating to definitions of workflow and measurement, definitions of health IT, samples, study quality, and socio-technical context. Each of these factors is discussed in this chapter.

Workflow Definitions and Measuring Workflow

The literature review in this report is a first attempt to examine workflow changes across a wide variety of types of health IT systems and care settings and highlights many weaknesses of the body of research. Less than 15 percent of the articles found were focused on the topics of clinical workflow change related to health IT implementation or workflow analysis using health IT as a tool. Another 6 percent of articles were focused on acceptance and 3 percent on usability. For the remaining 75 percent of studies, the workflow findings had to be pulled from articles that primarily discussed health IT implementation and use. This meant that the amount of evidence supporting the results varied, from measured differences in the durations of consultations in an RCT[121] to anecdotal evidence based on the author's experience in a single-clinic implementation.[153] Some findings are relatively well supported by scientific evidence in a pre-post study without a control group, others are anecdotal asides in an RCT.

Because no standard definition of workflow exists (see Unertl[305] for a comprehensive list of definitions), workflow measures varied substantially in this literature. Effects of health IT systems on workflow were indicated by changes to, for example, communication patterns, treatment adherence, guideline adherence, consultation time, travel time, distribution of tasks, information flow, health IT click patterns, number of visits, waiting time, referral time, or workload. This diversity of measures raises several issues. First, it makes comparisons between studies difficult, if not impossible. Second, many possible workflow measures could be impacted by the implementation and use of health IT systems, but a single study is likely to measure only fraction of the total. Although understandable, we must emphasize that each individual study only speaks to a subset of the workflow changes that may have occurred.

The diverse sets of workflow variables can be coarsely divided into those that use distal workflow measures and those that measure more proximal workflow changes. As mentioned previously, distal measures are those examining rates of preventive services, adherence to guidelines and procedures, and patient outcomes without clearly explaining how workflow has changed. Even in articles where the relationship between distal measures and workflow change is made explicit, the analysis of workflow change needs to be systematic. Otherwise we cannot determine how health IT affected workflow or how much it was affected.

Other papers studied proximal measures of workflow such as efficiency, processing time, use patterns, and coordination, e.g., Zheng et al.[28] To understand the impact of health IT on workflow in more depth and with more precision, we need studies that that link diverse proximal measures to distal measures. However, such research would require more theoretical developments linking the proximal and distal measures to provide measurement specificity and clearly describe the relationship between the proximal and distal outcomes.

Another limitation in the literature was a lack of study on the topic of administrative workflows such as those related to registration, regulation compliance, and billing. Health IT certainly has significant impacts on the workflows of those processes, but little evidence exists. Also, few of the studies examined how health IT could be used to improve or redesign clinic workflow. Fifty-four studies were identified that used health IT to study workflow (e.g., using computer generated logs to analyze use of clinical decision support), of which only 13 were identified that used health IT to redesign workflow. The rest used health IT as a data capture tool for evaluation purposes.

Definitions and Functions of Health IT

The studies used varied definitions of several types of health IT, notably telemedicine, e-prescribing, and EHR. Even when a system was well described, it only served to highlight the differences in each type of health IT application. Each vendor creates a different EHR, yet EHRs made by the same vendor also differ after being implemented in diverse institutions. Even within a single institution, the functionality used in units and clinics may differ. This fact limits the generalizability of single studies and speaks to the importance of research synthesis. In addition, studies provided limited description of the health IT intervention, its functionality, and other variables (e.g., implementation process).

Samples

Generalizability is also limited by the fact that most of the research was done in large practices affiliated with medical centers, HMOs, or national health systems outside the US. We only found two studies that focused on unaffiliated practices, though affiliation status was not known for the clinics in another 72 articles. Some results of the research performed in large clinics is likely to be true regardless of the setting, e.g., computer use in the exam room has the potential to disrupt patient-physician communication,[75] but others may not be, e.g., information flow among the care team improved because of secure messaging.[47]

Study Design

Only 18 percent of the studies meeting our inclusion criteria were randomized controlled trials. Only 4 percent were pre-post designs with control groups. The remaining original studies were of lesser quality designs, making evaluation of results difficult. As Table 17 shows, except in the case of studies examining decision support, the modal design was that of a post-only with no control group, a weak design for inferring causality.

Table 17: Study design of articles analyzing selected types of health IT

	Number of articles	Percentages
Type of Health IT		
EHR/EMR and CPOE	50	100.0%
Randomized controlled trials (RCT)	5	10.0%
Pre-post with control group	1	2.0%
Pre-post no control group	10	20.0%
Only Post with control group	2	4.0%
Only Post no control group	22	44.0%
Systematic literature review	7	14.0%
Other	3	6.0%
Decision Support, including alerts and reminders	77	100.0%
Randomized controlled trials (RCT)	23	29.9%
Pre-post with control group	6	7.8%
Pre-post no control group	8	10.4%
Only Post with control group	5	6.5%
Only Post no control group	15	19.5%
Systematic literature review	20	26.0%
Telemedicine	36	100.0%
Randomized controlled trials (RCT)	8	22.2%
Pre-post with control group	1	2.8%
Pre-post no control group	4	11.1%
Only Post with control group	5	13.9%
Only Post no control group	12	33.3%
Systematic literature review	5	13.9%
Narrative	1	2.8%
TOTAL	192	100.0%
Randomized controlled trial (RCT)	35	18.1%
Pre-post with control group	8	4.1%
Pre-post without control group	28	14.5%
Only Post with control group	15	7.8%
Only Post without control group	68	35.8%
Systematic literature review	30	15.5%
Narrative	4	2.1%
Other	4	2.1%

Another complicating factor is that few of the studies provided all of the details recommended by Talmon et al.[306] for evaluation studies of health IT. Study designs were not always obvious, rarely was a theoretical background provided, participants were not always well described, and measures and analytical methods were not always provided.

However, planning a RCT to evaluate a health IT implementation is very difficult. In many cases, groups cannot be created that differ only in the random assignment to the intervention or control conditions. Regardless of whether the intervention and control groups are comprised of physicians working in different clinics or different departments within a clinic, they are likely to differ in ways other than implementing the health IT application. Even within a single practice or department, physicians may have very different practice styles and workflows at baseline, which creates confounding. Rigorous assessments of the impact of health IT on workflow or on the use of health IT to improve workflow will be challenging. We encourage the exploration of designs other than RCTs, particularly pre-post studies and in-depth case studies that can help develop hypotheses.

Socio-technical Context

Equally important is that most of the studies did not provide sufficient information on the context with which to evaluate the impact of the health IT on workflow, even when an RCT was used. It is commonly assumed that when a health IT is implemented, subsequent changes, positive or negative, are caused by the health IT. However, perfectly confounded with any health IT implementation can be any one of the following:

- Functionality of the system;
- Usability of the system;
- Training—amount, quality, and latency between training and go-live;
- Technical support—duration, density, and quality;
- User participation—who participates, when, and quality;
- Top management commitment—money, time, and resources;
- Culture;
- Timeline of implementation; and
- Location and physical ergonomic considerations of the hardware.

Each of those factors, and many others that have been studied as part of implementation science,[307, 308] has an impact on process and outcomes. The studies meeting our inclusion criteria typically provided descriptions of functionality. Some also provided information about training, but this information was generally less detailed. The other factors were rarely discussed, and when mentioned, details were lacking. For example, Christakis et al.[97] state that "a computer workstation was placed in each examination room as well as in the physician work area and nursing stations" (p. 1). This information provides useful context, but the authors fail to describe where the computers were positioned relative to patients in the room or the size of the computer monitor, for example. As such, when a study found that health IT had a positive or negative impact on workflow, we could not tell how much of the effect may have been related to poor training, positive culture, poor usability, or other variables. In contrast, one article did provide excellent detail on the socio-technical context of a decision support implementation: Goldstein et al 2004.[62] This is a rare exception, however. Some studies, such as Eccles et al. 2002,[68] speculated that contextual factors (in this case training) could partially explain their null findings. Without systematic assessment of socio-technical context factors, however, solid determinations are difficult to make.

We recommend that the criteria recommended by Talmon et al.[306] for reporting on health IT studies be expanded to include socio-technical variables that are inherent in health IT implementation. We recommend future studies provide detail about:

- Hardware and physical layouts of the computer systems, including at minimum where computers are available, where they are stationed relative to patient seating in exam rooms and monitor size;
- Specific functionality;
- Evidence of usability, if any;
- Training—amount, quality, latency between training and go-live, whether the training system was the same as the implemented system, competency assessments, requirements to complete training, and tracking of training completion;
- Technical support—duration, density, and quality;
- User participation—who participated, when, and quality;
- Top management commitment—money, time, and resources;
- Change management processes—new structures to manage the change, participants in change management, and resources devoted to change management;
- Culture—evidence of supportiveness; and
- Timeline of implementation.

Conclusion

Although our literature review unearthed a great deal of information on (1) the effects of health IT implementation on workflow and (2) the use of health IT to analyze workflow, the quality of the findings is lacking for many reasons. Most of the articles we found were not focused directly on workflow, so the quality of evidence related to workflow change varied substantially. Workflow measures also include such a variety of topics that comparisons and generalizations are difficult to make. Even the definition of a specific type of health IT (e.g., e-prescribing) varied across articles, making comparisons even more difficult.

The majority of studies described research completed in large clinics affiliated with academic medical centers, health maintenance organizations, or national health systems outside the US. This greatly limits the generalizability of our findings for the small and medium-sized clinics that are the end users of the toolkit. Also, although a substantial minority of articles were RCTs, most of the studies did not use a scientifically rigorous design, limiting inferences of causality. Finally, most of the literature did not include descriptions of the socio-technical context of health IT implementation and use, making it difficult to understand the role of conflating or mediating factors such as training, technical support and organizational culture. Thus, although our findings on workflow change and analysis are suggestive, intriguing and sometimes consistent across many studies, more research is needed to draw firm conclusions about the relationships between health IT and workflow in ambulatory settings.

Chapter 5. Conclusions

In completing the tasks for this project, we have gathered a great deal of information about the effects of health IT implementation on workflow and the use of health IT to analyze workflow. Awareness is growing of the need to analyze workflow in order to ensure successful health IT implementation and the potential for health IT be used in process improvement. Our sources of information included peer-reviewed literature, grey literature, organizations helping clinics to implement, health IT vendors, and professional associations. We have discovered that some workflow changes associated with implementation seem to be nearly universal, such as the increased workload of physicians who have implemented an EHR. Others may be unique to the context of a particular clinic, such as the refusal of a physician to use new health IT application. Unfortunately, most of the evidence that fills this report is anecdotal, weakly supported, or otherwise questionable in terms of scientific rigor.

Nevertheless, the information has been important in shaping the toolkit. We have gleaned useful facts about the end users for whom we are creating the toolkit, their likely needs and the best way to provide information so that it will be useful to them. We have also discovered stories of health IT implementation and use that may provide other clinics with helpful foreknowledge. Most importantly, we have compiled a very comprehensive list of tools for workflow analysis, their advantages, disadvantages, and how to use them. From this list we have selected a small group of basic tools that would be most helpful to our end users. The basic tools are presented by stage in the implementation process: (1) considering implementation, (2) selecting a vendor, (3) preparing for installation, and (4) post implementation. Toolkit users may select each stage for detailed information on the basic tool(s) that may be useful.

The toolkit is the culmination of all the processes described in this report. It brings together information gathered from contacting organizations, reading countless Web sites, speaking with experts and reviewing thousands of journal articles. We hope it will prove useful to the small and medium-sized practices that are facing the daunting challenge of large-scale health IT implementations.

References

1. Institute of Medicine, editor. To Err is Human: Building a Safer Health System. Washington DC: National Academy Press; 2000.

2. Institute of Medicine, editor. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington DC: National Academy Press; 2001.

3. Institute of Medicine. Preventing Medication Errors. Washington DC: National Academy Press; 2007.

4. Shojania KG, Duncan B, McDonald K, et al. Making healthcare safer: a critical analysis of patient safety practices. Rockville, MD: Agency for Healthcare Research and Quality. Evidence Report/Technology Assessment No. 43; AHRQ publication 01-E058; 2001.

5. The Leapfrog Group. The Leapfrog Group for patient safety: rewarding higher standards. 2004 [cited March 6, 2004]; Available from: http://www.leapfroggroup.org

6. The White House National Economic Council. Reforming Healthcare for the 21st Century. 2006 [cited June 25, 2007]; Available from: http://www.whitehouse.gov/stateoftheunion/2006/healthcare/healthcare_booklet.pdf

7. US Department of Health and Human Services. Office of the National Coordinator for Health Information Technology: President's Vision for Health IT. 2005 [cited June 23, 2007]; Available from: http://www.hhs.gov/healthit/presvision.html

8. US Department of Health and Human Services. CMS: Centers for Medicare & Medicaid Services. EHR Incentive Programs. 2010 [cited July 1, 2010]; Available from: https://www.cms.gov/EHRIncentivePrograms/.

9. Carayon P, Hundt AS, Karsh B, et al. Work system design for patient safety: the SEIPS model. Quality and Safety in Healthcare 2006;15(Suppl I): i50-i8.

10. Shekelle P, Morton SC, Keeler EB, et al. Costs and Benefits of Health Information Technology: Agency for Healthcare Research and Quality; 2006. No. 132.

11. US Department of Health and Human Services. Medicare and Medicaid Programs; Electronic Health Record Incentive Program; Final Rule. Federal Register 2010;75(144):44314 - 588.

12. Montori VM, Dinneen SF, Gorman CA, et al. The impact of planned care and a diabetes electronic management system on community-based diabetes care - The Mayo Health System Diabetes Translation Project. Diabetes Care 2002 Nov;25(11):1952-7.

13. Weber V, Bloom F, Pierdon S, et al. Employing the electronic health record to improve diabetes care: A multifaceted intervention in an integrated delivery system. Journal of General Internal Medicine 2008 Apr;23(4):379-82.

14. Garets D, Davis M. Electronic Medical Records vs. Electronic Health Records:Yes, There Is a Difference: Healthcare Information and Management Systems Society (HIMSS); 2006.

15. National Alliance for Health Information Technology (NAHIT). Report to the Office of the National Coordinator for Health Information Technology on Defining Key Health Information Technology Terms: Department of Health and Human Services (DHHS); 2008.

16. Fung CH. Computerized Condition-specific Templates for Improving Care of Geriatric Syndromes in a Primary Care Setting. Journal of General Internal Medicine 2006;21(9):989-94.

17. Hsu J, Huang J, Fung V, et al. Health information technology and physician-patient interactions: Impact of computers on communication during outpatient primary care visits. Journal of the American Medical Informatics Association 2005 Jul-Aug;12(4):474-80.

18. Margalit RS, Roter D, Dunevant MA, et al. Electronic medical record use and physician-patient communication: An observational study of Israeli primary care encounters. Patient Education and Counseling 2006 Apr;61(1):134-41.

19. Ventres W, Kooienga S, Marlin R, et al. Clinician style and examination room computers: A video ethnography. Family Medicine 2005 Apr;37(4):276-81.

20. Rose AF, Schnipper JL, Park ER, et al. Using qualitative studies to improve the usability of an EMR. Journal of Biomedical Informatics 2005;38(1):51-60.

21. Morris CJ, Cantrill JA, Avery AJ, et al. Preventing drug related morbidity: a process for facilitating changes in practice. Quality & Safety in Health Care 2006;15(2):116-21.

22. Arar NH, Wen L, McGrath J, et al. Communicating about medications during primary care outpatient visits: the role of electronic medical records. Informatics in Primary Care 2005;13(1):13-21.

23. Bostrom AC, Schafer P, Dontje K, et al. Electronic health record: implementation across the Michigan Academic Consortium. CIN: Computers, Informatics, Nursing 2006 Jan-Feb;24(1):44-52.

24. Chen C, Garrido T, Chock D, et al. The Kaiser Permanente Electronic Health Record: Transforming And Streamlining Modalities Of Care. Health Affairs 2009 Mar-Apr;28(2):323-33.

25. O'Connell RT, Cho C, Shah N, et al. Take note(s): Differential EHR satisfaction with two implementations under one roof. Journal of the

American Medical Informatics Association 2004 Jan-Feb;11(1):43-9.

26. Pizziferri L, Kittler AF, Volk LA, et al. Primary care physician time utilization before and after implementation of an electronic health record: A time-motion study. Journal of Biomedical Informatics 2005;38(3):176-88.

27. Zandieh SO, Yoon-Flannery K, Kuperman GJ, et al. Challenges to EHR implementation in electronic-versus paper-based office practices. Journal of General Internal Medicine 2008 Jun;23(6):755-61.

28. Zheng K, Padman R, Johnson MP, et al. An Interface-driven Analysis of User Interactions with an Electronic Health Records System. Journal of the American Medical Informatics Association 2009;16(2):228-37.

29. Krall M. Acceptance and performance by clinicians using an ambulatory electronic medical record in an HMO. Annual Symposium on Computer Application in Medical Care; 1995; Philadelphia, PA: American Medical Informatics Association; 1995. p. 708.

30. Overhage JM, Perkins S, Tierney WM, et al. Controlled trial of direct physician order entry: effects on physicians' time utilization in ambulatory primary care internal medicine practices. Journal of the American Medical Informatics Association 2001;8(4):361-9.

31. Lorenzi NM, Kouroubali A, Detmer DE, et al. How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. BMC Medical Informatics and Decision Making 2009;9:15.

32. Miller RH, West C, Brown TM, et al. The Value Of Electronic Health Records In Solo Or Small Group Practices. Health Affairs 2005;24(5):1127.

33. Christensen T, Grimsmo A. Instant availability of patient records, but diminished availability of patient information: a multi-method study of GP's use of electronic patient records. BMC Medical Informatics & Decision Making 2008;8:12.

34. Campbell JR, Givner N, Seelig CB, et al. Computerized medical records and clinic function. MD Computing 1989;6(5):282-7.

35. Carayon P, Smith P, Hundt AS, et al. Implementation of an electronic health records system in a small clinic: the viewpoint of clinic staff. Behaviour & Information Technology 2009 2009 Jan-Feb;28(1):5-20.

36. Chan WS, Stevenson M, McGlade K. Do general practitioners change how they use the computer during consultations with a significant psychological component? International Journal of Medical Informatics 2008 Aug;77(8):534-8.

37. Gamm LD, Barsukiewicz CK, Dansky KH, et al. Pre- and post- control model research on end-users' satisfaction with an electronic medical record: Preliminary results. Journal of the American Medical Informatics Association 1998:225-9.

38. Nemeth LS, Wessell AM, Jenkins RG, et al. Strategies to accelerate translation of research into primary care within practices using electronic medical records. Journal of Nursing Care Quality 2007 Oct-Dec;22(4):343-9.

39. Randeree E. Exploring physician adoption of EMRs: A multi-case analysis. Journal of Medical Systems 2007 Dec;31(6):489-96.

40. Rollman BL, Hanusa BH, Gilbert T, et al. The electronic medical record. Archives of Internal Medicine 2001 Jan;161(2):189-97.

41. Rouf E, Whittle J, Lu N, et al. Computers in the exam room: Differences in physician-patient interaction may be due to physician experience. Journal of General Internal Medicine 2007 Jan;22(1):43-8.

42. Shachak A, Hadas-Dayagi M, Ziv A, et al. Primary Care Physicians' Use of an Electronic Medical Record System: A Cognitive Task Analysis. Journal of General Internal Medicine 2009 Mar;24(3):341-8.

43. Haynes RB, Walker CJ. Computer-Aided Quality Assurance: A Critical Appraisal. Archives of Internal Medicine 1987 Jul;147(7):1297-301.

44. Chaudhry B, Wang J, Wu SY, et al. Systematic review: Impact of health information technology on quality, efficiency, and costs of medical care. Annals of Internal Medicine 2006 May;144(10):742-52.

45. Mitchell E, Sullivan F. A descriptive feast but an evaluative famine: systematic review of published articles on primary care computing during 1980-97. British Medical Journal 2001 Feb;322(7281):279-82E.

46. Keyser DJD, Jacob W; Kmetik, Karen; Antman, Mark S; Sirio, Carl A. and Farley, Donna O. . Using Health Information Technology-Related Performance Measures and Tool to Improve Chronic Care. The Joint Commission Journal on Quality and Patient Safety 2009;35(5):248-55.

47. Miller RH, Sim I. Physicians' use of electronic medical records: Barriers and solutions. Health Affairs 2004 Mar-Apr;23(2):116-26.

48. Morris L, Taylor M, Campbell LM, et al. How will practices cope with information for the new GMS contract? Coronary heart disease data recording in five Scottish practices. Informatics in Primary Care 2003;11(3):121-7.

49. Schade CP, Sullivan FM, Lusignan S, et al. e-Prescribing, efficiency, quality: Lessons from the computerization of UK family practice. Journal of the American Medical Informatics Association 2006 Sep-Oct;13(5):470-5.

50. Simon SR, Kaushal R, Cleary PD, et al. Physicians and electronic health records - A statewide survey. Archives of Internal Medicine 2007 Mar;167(5):507-12.

51. Dansky KH, Gamm LD, Vasey JJ, et al. Electronic medical records: Are physicians ready? / Practitioner

application. Journal of Healthcare Management 1999;44(6):440.

52. McDonald T, Blignaut PJ. A comparison of a manual and a computer system in a primary health care clinic. Curationis 1998;21(3):8-13.

53. Rotich JK, Hannan TJ, Smith FE, et al. Installing and implementing a computer-based patient record system in sub-Saharan Africa: the Mosoriot Medical Record System. Journal of the American Medical Informatics Association 2003;10(4):295-303.

54. Ash JS, Sittig DF, Dykstra RH, et al. Categorizing the unintended sociotechnical consequences of computerized provider order entry. International Journal of Medical Informatics 2007;76(SUPPL 1):21-7.

55. Eslami S, Abu-Hanna A, de Keizer NF. Evaluation of outpatient computerized physician medication order entry systems: a systematic review. Journal of the American Medical Informatics Association 2007;14(4):400-6.

56. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety - A systematic review. Archives of Internal Medicine 2003 Jun;163(12):1409-16.

57. Kuperman GJ, Gibson RF. Computer physician order entry: Benefits, costs, and issues. Annals of Internal Medicine 2003 Jul;139(1):31-9.

58. Safran C, Jones PC, Rind D, et al. Electronic communication and collaboration in a health care practice. Artificial Intelligence in Medicine 1998 Feb;12(2):137-51.

59. Smith MY, Depue JD, Rini C. Computerized decision-support systems for chronic pain management in primary care. Pain Medicine 2007 Oct;8:S155-S66.

60. Dorr D, Bonner LM, Cohen AN, et al. Informatics systems to promote improved care for chronic illness: A literature review. Journal of the American Medical Informatics Association 2007 Mar-Apr;14(2):156-63.

61. Brownbridge G, Evans A, Fitter M, et al. An Interactive Computerized Protocol for the Management of Hypertension: Effects on the General-Practitioner's Clinical Behavior. Journal of the Royal College of General Practitioners 1986 May;36(286):198-202.

62. Goldstein MK, Coleman RW, Tu SW, et al. Translating research into practice: organizational issues in implementing automated decision support for hypertension in three medical centers. Journal of the American Medical Informatics Association 2004 Sep-Oct;11(5):368-76.

63. Hicks LS, Sequist TD, Ayanian JZ, et al. Impact of computerized decision support on blood pressure management and control: A randomized controlled trial. Journal of General Internal Medicine 2008 Apr;23(4):429-41.

64. Lobach DF, Hammond WE. Computerized decision support based on a clinical practice guideline improves compliance with care standards. American Journal of Medicine 1997 Jan;102(1):89-98.

65. Meigs JB, Cagliero E, Dubey A, et al. A controlled trial of web-based diabetes disease management - The MGH diabetes primary care improvement project. Diabetes Care 2003 Mar;26(3):750-7.

66. Sequist T, Gandhi T, Karson A, et al. A randomized trial of electronic clinical reminders to improve quality of care for diabetes and coronary artery disease. Journal of the American Medical Informatics Association 2005;12(4):431-7.

67. Bloomfield H, Nelson D, Van Ryn M, et al. A trial of education, prompts, and opinion leaders to improve prescription of lipid modifying therapy by primary care physicians for patients with ischemic heart disease. British Medical Journal 2005;14(4):258.

68. Eccles M, McColl E, Steen N, et al. Effect of computerised evidence based guidelines on management of asthma and angina in adults in primary care: cluster randomised controlled trial. BMJ: British Medical Journal 2002;325(7370):941-4.

69. Tierney WM, Overhage JM, Murray MD, et al. Effects of computerized guidelines for managing heart disease in primary care - A randomized, controlled trial. Journal of General Internal Medicine 2003 Dec;18(12):967-76.

70. Toth-Pal E, Wardh I, Strender L-E, et al. Implementing a clinical decision-support system in practice: A qualitative analysis of influencing attitudes and characteristics among general practitioners. Informatics for Health & Social Care 2008;33(1):39-54.

71. Kuilboer MM, van Wijk MAM, Mosseveld M, et al. Computed critiquing integrated into daily clinical practice affects physicians' behavior - A randomized clinical trial with AsthmaCritic. Methods of Information in Medicine 2006;45(4):447-54.

72. McCowan C, Neville RG, Ricketts IW, et al. Lessons from a randomized controlled trial designed to evaluate computer decision support software to improve the management of asthma. Medical Informatics and the Internet in Medicine 2001 Jul-Sep;26(3):191-201.

73. Tierney WM, Overhage JM, Murray MD, et al. Can computer-generated evidence-based care suggestions enhance evidence-based management of asthma and chronic obstructive pulmonary disease? A randomized, controlled trial. Health Services Research 2005 Apr;40(2):477-97.

74. Rubenstein LV, McCoy JM, Cope DW, et al. Improving Patient Quality-of-Life with Feedback to Physicians about Functional Status. Journal of General Internal Medicine 1995 Nov;10(11):607-14.

75. Zheng K, Padman R, Johnson MP, et al. Understanding technology adoption in clinical care: Clinician adoption behavior of a point-of-care reminder system.

International Journal of Medical Informatics 2005;74(7-8):535-43.

76. Litzelman DK, Dittus RS, Miller ME, et al. Requiring Physicians to Respond to Reminders Improves their Compliance with Preventative Care Protocols. Journal of General Internal Medicine 1993;8(6):311-7.

77. McDonald CJ, Hui SL, Smith DM, et al. Reminders to Physicians from an Introspective Computer Medical Record. Annals of Internal Medicine 1984;100(1):130-8.

78. McDowell I, Newell C, Rosser W. Computerized Reminders to Encourage Cervical Screening in Family-Practice. Journal of Family Practice 1989 Apr;28(4):420-4.

79. Emery J, Morris H, Goodchild R, et al. The GRAIDS trial: a cluster randomised controlled trial of computer decision support for the management of familial cancer risk in primary care. British Journal of Cancer 2007 Aug;97(4):486-93.

80. Jimbo M, Nease DE, Ruffin MT, et al. Information technology and cancer prevention. CA: A Cancer Journal for Clinicians 2006 Jan-Feb;56(1):26-36.

81. Nease DE, Ruffin MT, Klinkman MS, et al. Impact of a generalizable reminder system on colorectal cancer screening in diverse primary care practices - A report from the prompting and reminding at encounters for prevention project. Medical Care 2008 Sep;46(9):S68-S73.

82. Rosser WW, Hutchison BG, McDowell I, et al. Use of Reminders to Increase Compliance with Tetanus Booster Vaccination. Canadian Medical Association Journal 1992 Mar;146(6):911-7.

83. McDowell I, Newell C, Rosser W. A Randomized Trial of Computerized Reminders for Blood Pressure Screening in Primary Care. Medical Care 1989;27(3):297-305.

84. Goetz MB, Bowman C, Hoang T, et al. Implementing and evaluating a regional strategy to improve testing rates in VA patients at risk for HIV, utilizing the QUERI process as a guiding framework: QUERI Series. Implementation Science 2008 Mar;3.

85. Ornstein S, Garr D, Jenkins R, et al. Implementation and evaluation of a computer-based preventive services system. Family Medicine 1995;27(4):260.

86. Saleem JJ, Patterson ES, Militello L, et al. Exploring barriers and facilitators to the use of computerized clinical reminders. Journal of the American Medical Informatics Association 2005;12(4):438-47.

87. Durieux P, Trinquart L, Colombet I, et al. Computerized advice on drug dosage to improve prescribing practice. Cochrane Database of Systematic Reviews 2008;3.

88. Mollon B, Chong JJR, Holbrook AM, et al. Features predicting the success of computerized decision support for prescribing: a systematic review of randomized controlled trials. BMC Medical Informatics and Decision Making 2009 Feb;9.

89. Shebl NA, Franklin BD, Barber N. Clinical decision support systems and antibiotic use. Pharmacy World & Science 2007 Aug;29(4):342-9.

90. Shah NR, Seger AC, Seger DL, et al. Improving acceptance of computerized prescribing alerts in ambulatory care. Journal of the American Medical Informatics Association 2006 Jan-Feb;13(1):5-11.

91. Tamblyn R, Huang A, Perreault R, et al. The medical office of the 21st century (MOXXI): effectiveness of computerized decision-making support in reducing inappropriate prescribing in primary care. Canadian Medical Association Journal 2003 Sep;169(6):549-56.

92. Walton RT, Gierl C, Yudkin P, et al. Evaluation of computer support for prescribing (CAPSULE) using simulated cases. British Medical Journal 1997 Sep;315(7111):791-5.

93. Kuperman GJ, Bobb A, Payne TH, et al. Medication-related clinical decision support in computerized provider order entry systems: A review. Journal of the American Medical Informatics Association 2007 Jan-Feb;14(1):29-40.

94. Roland MO, Zander LI, Evans M, et al. Evaluation of a computer assisted repeat prescribing programme in a general practice. British Medical Journal (Clinical Research Ed.) 1985 Aug 17;291(6493):456-8.

95. Schectman JM, Schorling JB, Nadkarni MM, et al. Determinants of physician use of an ambulatory prescription expert system. International Journal of Medical Informatics 2005 Sep;74(9):711-7.

96. Weingart SN, Toth M, Sands DZ, et al. Physicians' decisions to override computerized drug alerts in primary care. Archives of Internal Medicine 2003 Nov;163(21):2625-31.

97. Christakis DA, Zimmerman FJ, Wright JA, et al. A randomized controlled trial of point-of-care evidence to improve the antibiotic prescribing practices for otitis media in children. Pediatrics 2001 Feb;107(2):e15.

98. Fitzmaurice DA, Hobbs FDR, Murray ET, et al. Evaluation of computerized decision support for oral anticoagulation management based in primary care. British Journal of General Practice 1996 Sep;46(410):533-5.

99. Monane M, Matthias DM, Nagle BA, et al. Improving prescribing patterns for the elderly through an online drug utilization review intervention - A system linking the physician, pharmacist, and computer. JAMA-Journal of the American Medical Association 1998 Oct;280(14):1249-52.

100. Samore MH, Bateman K, Alder SC, et al. Clinical decision support and appropriateness of antimicrobial prescribing - A randomized trial. Jama-Journal of the American Medical Association 2005 Nov;294(18):2305-14.

101. Magnus D, Rodgers S, Avery AJ. GPs' views on computerized drug interaction alerts: questionnaire survey. Journal of Clinical Pharmacy and Therapeutics 2002 Oct;27(5):377-82.

102. eHealth Initiative. Electronic Prescribing: Becoming Mainstream Practice; 2008.

103. US Department of Health and Human Services. Electronic Prescribing (e-prescribing, eRx). 2010 [cited July 7, 2010]; Available from: http://healthit.hhs.gov/portal/server.pt?open=512&mode=2&cached=true&objID=1220

104. Crosson JC, Isaacson N, Lancaster D, et al. Variation in electronic prescribing implementation among twelve ambulatory practices. Journal of General Internal Medicine 2007 Apr;23(4):364-71.

105. Murray MD, Loos B, Tu W, et al. Effects of computer-based prescribing on pharmacist work patterns. Journal of the American Medical Informatics Association 1998 Nov-Dec;5(6):546-53.

106. Ross S, Papshev D, Murphy E, et al. Effects of electronic prescribing on formulary compliance and generic drug utilization in the ambulatory care setting: a retrospective analysis of administrative claims data. Journal of Managed Care Pharmacy: JMCP 2005;11(5):410.

107. Hollingworth W, Devine EB, Hansen RN, et al. The impact of e-Prescribing on prescriber and staff time in ambulatory care clinics: a time-motion study. Journal of the American Medical Informatics Association 2007;14(6):722-30.

108. Rivkin S. Opportunities and challenges of electronic physician prescribing technology. Medical Interface 1997;10(8):77.

109. Wogen S, Fulop G, Heller J. Improving the efficiency of the prescription process and promoting plan adherence. Drug Benefit Trends 2003;15(9):35-40.

110. American Telemedicine Association. Telemedicine: A Brief Overview. Congressional Telehealth Briefing. Washington, DC; 1999.

111. Norris AC. Essentials of Telemedicine and Telecare. New York: John Wiley & Sons; 2002.

112. Du Moulin MFMT, Bullens-Goessens YIJM, Henquet CJM, et al. The reliability of diagnosis using store-and-forward teledermatology. Journal of Telemedicine and Telecare 2003 September 1, 2003;9(5):249-52.

113. Berghout RM, Eminovic N, de Keizer NF, et al. Evaluation of general practitioner's time investment during a store-and-forward teledermatology consultation. International Journal of Medical Informatics 2007 Dec;76 Suppl 3:S384-91.

114. Perednia D, Wallace J, Morrisey M, et al. The effect of a teledermatology program on rural referral patterns to dermatologists and the management of skin disease. Studies in Health Technology and Informatics 1998;52:290.

115. Whited J, Hall R, Foy M, et al. Teledermatology's impact on time to intervention among referrals to a dermatology consult service. Telemedicine Journal and E-Health 2002;8(3):313-21.

116. Harrison PV, Kirby B, Dickinson Y, et al. Teledermatology-high technology or not? Journal of Telemedicine and Telecare 1998 March 15, 1998;4(suppl_1):31-2.

117. Nordal EJ, Moseng D, Kvammen B, et al. A comparative study of teleconsultations versus face-to-face consultations. Journal of Telemedicine and Telecare 2001 October 1, 2001;7(5):257-65.

118. Oakley AMM, Kerr P, Duffill M, et al. Patient cost-benefits of realtime teledermatology-a comparison of data from Northern Ireland and New Zealand. Journal of Telemedicine and Telecare 2000 April 1, 2000;6(2):97-101.

119. Chan D, Callahan C, Sheets S, et al. An Internet-based store-and-forward video home telehealth system for improving asthma outcomes in children. American Journal of Health System Pharmacy 2003 October 1, 2003;60(19):1976-81.

120. Chase H, Pearson J, Wightman C, et al. Modem transmission of glucose values reduces the costs and need for clinic visits. Diabetes Care 2003;26(5):1475.

121. Kruger DF, White K, Galpern A, et al. Effect of modem transmission of blood glucose data on telephone consultation time, clinic work flow, and patient satisfaction for patients with gestational diabetes mellitus. Journal of the American Academy of Nurse Practitioners 2003;15(8):371-5.

122. Larizza C, Bellazzi R, Stefanelli M, et al. The M2DM Project--the experience of two Italian clinical sites with clinical evaluation of a multi-access service for the management of diabetes mellitus patients. Methods of Information in Medicine 2006;45(1):79-84.

123. Chumbler N, Mann W, Wu S, et al. The association of home-telehealth use and care coordination with improvement of functional and cognitive functioning in frail elderly men. Telemedicine Journal & e-Health 2004;10(2):129-37.

124. Terschuren C, Fendrich K, van den Berg N, et al. Implementing telemonitoring in the daily routine of a GP practice in a rural setting in northern Germany. Journal of Telemedicine and Telecare 2007;13(4):197-201.

125. Currell R, Urquhart C, Wainwright P, et al. Telemedicine versus face to face patient care: effects on professional practice and health care outcomes. Cochrane Database of Systematic Reviews. Chichester, UK: John Wiley & Sons, Ltd; 2000.

126. Roine R, Ohinmaa A, Hailey D. Assessing telemedicine: a systematic review of the literature. Canadian Medical Association Journal 2001;165(6):765-71.

127. Jarvis-Selinger S, Chan E, Payne R, et al. Clinical telehealth across the disciplines: Lessons learned. Telemedicine and e-Health 2008;14(7):720-5.

128. Hakansson S, Gavelin C. What do we really know about the cost-effectiveness of telemedicine? J Telemed Telecare 2000 February 10, 2000;6(suppl_1):133-6.

129. MacFarlane A, Clerkin P, Murphy A. Role flexibility among telemedicine service providers in the north-west and west of Ireland. Journal of Telemedicine and Telecare 2005;11(Supplement 1):62.

130. Aas IH. Telemedicine and changes in the distribution of tasks between levels of care. J Telemed Telecare 2002;8 Suppl 2:1-2.

131. Miyasaka K, Suzuki Y, Sakai H, et al. Interactive communication in high-technology home care: Videophones for pediatric ventilatory care. Pediatrics 1997 Jan;99(1):E11-E6.

132. Woods KF, Johnson JA, Kutlar A, et al. Sickle cell disease telemedicine network for rural outreach. Journal of Telemedicine and Telecare 2000 October 1, 2000;6(5):285-90.

133. Jaatinen PT, Aarnio P, Remes J, et al. Teleconsultation as a replacement for referral to an outpatient clinic. Journal of Telemedicine and Telecare 2002 April 1, 2002;8(2):102-6.

134. Ullah R, Gilliland D, Adams D. Otolaryngology consultations by real-time telemedicine. The Ulster Medical Journal 2002;71(1):26.

135. Balas E, Jaffrey F, Kuperman G, et al. Electronic communication with patients. Evaluation of distance medicine technology. JAMA: Journal of the American Medical Association 1997;278(2):152-9.

136. Davis P, Howard R, Brockway P. An evaluation of telehealth in the provision of rheumatologic consults to a remote area. Journal of Rheumatology 2001 Aug;28(8):1910-3.

137. Haukipuro K, Ohinmaa A, Winblad I, et al. The feasibility of telemedicine for orthopaedic outpatient clinics: a randomized controlled trial. Journal of Telemedicine and Telecare 2000;6(4):193.

138. Pacht E, Turner J, Gailiun M, et al. Effectiveness of telemedicine in the outpatient pulmonary clinic. Telemedicine Journal: the official journal of the American Telemedicine Association 1998;4(4):287.

139. Soopramanien A, Pain H, Stainthorpe A, et al. Using telemedicine to provide post-discharge support for patients with spinal cord injuries. Journal of Telemedicine and Telecare 2005 July 1, 2005;11(suppl_1):68-70.

140. Kobb R, Hoffman N, Lodge R, et al. Enhancing elder chronic care through technology and care coordination: report from a pilot. Telemedicine Journal and E-Health 2003;9(2):189-95.

141. Raza T, Joshi M, Schapira RM, et al. Pulmonary telemedicine-A model to access the subspecialist services in underserved rural areas. International Journal of Medical Informatics 2009 Jan;78(1):53-9.

142. Marzegalli M, Lunati M, Landolina M, et al. Remote monitoring of CRT-ICD: The multicenter Italian CareLink evaluation - Ease of use, acceptance, and organizational implications. PACE-Pacing and Clinical Electrophysiology 2008 Oct;31(10):1259-64.

143. Whittaker SL, Adkins S, Phillips R, et al. Success factors in the long-term sustainability of a telediabetes programme. Journal of Telemedicine and Telecare 2004;10(2):84-8.

144. Friedman R, Kazis L, Jette A, et al. A telecommunications system for monitoring and counseling patients with hypertension. Impact on medication adherence and blood pressure control. American Journal of Hypertension 1996;9(4 Pt 1):285.

145. Harno K, Paavola T, Carlson C, et al. Patient referral by telemedicine: effectiveness and cost analysis of an intranet system. Journal of Telemedicine and Telecare 2000;6(6):320-9.

146. Logan AG, McIsaac WJ, Tisler A, et al. Mobile phone-based remote patient monitoring system for management of hypertension in diabetic patients. American Journal of Hypertension 2007 Sep;20(9):942-8.

147. Malasanos TH, Burlingame JB, Youngblade L, et al. Improved access to subspecialist diabetes care by telemedicine: cost savings and care measures in the first two years of the FITE diabetes project. Journal of Telemedicine and Telecare 2005 July 1, 2005;11(suppl_1):74-6.

148. Ou MH, West GA, Lazarescu M, et al. Evaluation of TELEDERM for dermatological services in rural and remote areas. Artificial Intelligence in Medicine 2008 Sep;44(1):27-40.

149. Guillen S, Arredondo MT, Traver V, et al. Multimedia telehomecare system using standard TV set. IEEE Transactions on Biomedical Engineering 2002;49(12 II):1431-7.

150. Pluye P, Grad RM, Dunikowski LG, et al. Impact of clinical information-retrieval technology on physicians: A literature review of quantitative, qualitative and mixed methods studies. International Journal of Medical Informatics 2005 Sep;74(9):745-68.

151. Bonnevie L, Thomsen T, Jorgensen T. The use of computerized decision support systems in preventive cardiology-principal results from the national PRECARD((R)) survey in Denmark. European Journal of Cardiovascular Prevention & Rehabilitation 2005 Feb;12(1):52-5.

152. Buchanan BG, Moore JD, Forsythe DE, et al. An intelligent interactive system for delivering individualized information to patients. Artificial Intelligence in Medicine 1995 Apr;7(2):117-54.

153. Pluye P, Grad RM. How information retrieval technology may impact on physician practice: an organizational case study in family medicine. Journal of Evaluation in Clinical Practice 2004 Aug;10(3):413-30.

154. Sciamanna CN, Marcus BH, Goldstein MG, et al. Feasibility of incorporating computer-tailored health behaviour communications in primary care settings. Informatics in Primary Care 2004;12(1):40-8.

155. Barnett GO, Barry MJ, Robb-Nicholson C, et al. Overcoming information overload: an information system for the primary care physician. Studies in Health Technology and Informatics 2004;107(Pt 1):273-6.

156. Huber JT, Varman B. Informing Neighborhood Health: a health information outreach project targeting community clinics. Journal of Consumer Health on the Internet 2006;10(2):37-45.

157. Jerome RN, Giuse NB, Rosenbloom ST, et al. Exploring clinician adoption of a novel evidence request feature in an electronic medical record system. Journal of the Medical Library Association 2008;96(1):34-41.

158. Cimino JJ, Patel VL, Kushniruk AW. Studying the human-computer-terminology interface. Journal of the American Medical Informatics Association 2001 Mar-Apr;8(2):163-73.

159. Kim J, Whitney A, Hayter S, et al. Development and initial testing of a computer-based patient decision aid to promote colorectal cancer screening for primary care practice. BMC Medical Informatics and Decision Making 2005;5:36.

160. McBride MR, Napier-Tibere B. Harnessing technology and collaboration for an online ethnogeriatric educational resource. Gerontology & Geriatrics Education 2004;24(4):61-75.

161. O'Brien C, Cambouropoulos P. Combating information overload: a six-month pilot evaluation of a knowledge management system in general practice. British Journal of General Practice 2000 Jun;50(455):489-90.

162. Redfern RO, Horii SC, Feingold E, et al. Radiology workflow and patient volume: Effect of picture archiving and communication systems on technologists and radiologists. Journal of Digital Imaging 2000;13(2 SUPPL 1):97-100.

163. Yusof MM, Kuljis J, Papazafeiropoulou A, et al. An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit). International Journal of Medical Informatics 2008 Jun;77(6):386-98.

164. Andriole KP, Luth DM, Gould RG. Workflow assessment of digital versus computed radiography and screen-film in the outpatient environment. Journal of Digital Imaging 2002;15 Suppl 1:124-6.

165. Arreola M, Rill LN. Enterprise-wide CR implementation: The Shands Healthcare System experience. Journal of Digital Imaging 2003 Jun;16(2):173-9.

166. Cammisa M, Guglielmi G, Zarrelli N, et al. Design and implementation of an integrated HIS-RIS-PACS system: our experience. Radiological Medicine 2004 Jan-Feb;107(1-2):102-12.

167. Dackiewicz D, Bergsneider C, Piraino D. Impact of digital radiography on clinical workflow and patient satisfaction. Journal of Digital Imaging 2000 May;13(2 Suppl 1):200-1.

168. de Lusignan S, Stephens PN, Adal N, et al. Does feedback improve the quality of computerized medical records in primary care? Journal of the American Medical Informatics Association 2002 Jul-Aug;9(4):395-401.

169. Gilmet GP, Mallon RP, Griffin BT, et al. The use of an integrated clinical laboratory and pharmacy diabetes database to provide physician performance feedback in an IPA-model HMO. Journal of Ambulatory Care Management 1998 Jan;21(1):12-23.

170. Pagliari C, Clark D, Hunter K, et al. DARTS 2000 online diabetes management system: formative evaluation in clinical practice. Journal of Evaluation in Clinical Practice 2003 Nov;9(4):391-400.

171. Patterson V, Humphreys J, Chua R. Email triage of new neurological outpatient referrals from general practice. Journal of Neurology, Neurosurgery & Psychiatry 2004 Apr;75(4):617-20.

172. Pagliari C, Gilmour M, Sullivan F. Electronic Clinical Communications Implementation (ECCI) in Scotland: a mixed-methods programme evaluation. Journal of Evaluation in Clinical Practice 2004 Feb;10(1):11-20.

173. Maass MC, Asikainen P, Maenpaa T, et al. Usefulness of a Regional Health Care Information System in primary care - A case study. Computer Methods and Programs in Biomedicine 2008 Aug;91(2):175-81.

174. Lang E, Afilalo M, Vandal AC, et al. Impact of an electronic link between the emergency department and family physicians: a randomized controlled trial. Canadian Medical Association Journal 2006 Jan;174(3):313-8.

175. Glazner JE, Beaty BL, Pearson KA, et al. Using an immunization registry: Effect on practice costs and time. Ambulatory Pediatrics 2004 Jan-Feb;4(1):34-40.

176. Cauldwell M, Beattie C, Cox B, et al. The impact of electronic patient records on workflow in general practice. Health Informatics Journal 2007;13(2):155-60.

177. Tufano JT, Ralston JD, Martin DP. Providers' Experience with an Organizational Redesign Initiative to Promote Patient-Centered Access: A Qualitative Study. Journal of General Internal Medicine 2008 Nov;23(11):1778-83.

178. Byrne JM, Elliott S, Firek A. Initial Experience with Patient-Clinician Secure Messaging at a VA Medical Center. Journal of the American Medical Informatics Association 2009 Mar-Apr;16(2):267-70.

179. McAlearney AS, Schweikhart SB, Medow MA. Organizational and Physician Perspectives about Facilitating Handheld Computer Use in Clinical Practice: Results of a Cross-Site Qualitative Study. Journal of the American Medical Informatics Association 2005;12(5):568-75.

180. Dexter PR, Wolinsky FD, Gramelspacher GP, et al. Effectiveness of computer-generated reminders for increasing discussions about advance directives and completion of advance directive forms - A randomized, controlled trial. Annals of Internal Medicine 1998 Jan;128(2):102-12.

181. John R, Buschman P, Chaszar M, et al. Development and evaluation of a PDA-based decision support system for pediatric depression screening. Studies in Health Technology and Informatics 2007;129(Pt 2):1382-6.

182. Rollman BL, Hanusa BH, Lowe HJ, et al. A randomized trial using computerized decision support to improve treatment of major depression in primary care. Journal of General Internal Medicine 2002 Jul;17(7):493-503.

183. af Klercker T, Zetraeus S. Dilemmas in introducing World Wide Web-based information technology in primary care: a focus group study. Family Practice 1998 Jun;15(3):205-10.

184. Berner ES, Maisiak RS, Cobbs CG, et al. Effects of a decision support system on physicians' diagnostic performance. Journal of the American Medical Informatics Association 1999 Sep-Oct;6(5):420-7.

185. Brownbridge G, Fitter M, Sime M. The doctor's use of a computer in the consulting room: An analysis. International Journal of Man-Machine Studies 1984;21(1):65-90.

186. Friedman CP, Elstein AS, Wolf FM, et al. Enhancement of clinicians' diagnostic reasoning by computer-based consultation - A multisite study of 2 systems. Jama-Journal of the American Medical Association 1999 Nov;282(19):1851-6.

187. Miller RA. Medical Diagnostic Decision-Support Systems - Past, Present, and Future - A Threaded Bibliography and Brief Commentary. Journal of the American Medical Informatics Association 1994 Jan-Feb;1(1):8-27.

188. Hoch I, Heymann AD, Kurman I, et al. Countrywide computer alerts to community physicians improve potassium testing in patients receiving diuretics. Journal of the American Medical Informatics Association 2003 Nov-Dec;10(6):541-6.

189. Steele AW, Eisert S, Witter J, et al. The effect of automated alerts on provider ordering behavior in an outpatient setting. Plos Medicine 2005 Sep;2(9):864-70.

190. Wolfstadt JI, Gurwitz JH, Field TS, et al. The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: A systematic review. Journal of General Internal Medicine 2008 Apr;23(4):451-8.

191. van Wijk MAM, van der Lei J, Mosseveld M, et al. Assessment of decision support for blood test ordering in primary care - A randomized trial. Annals of Internal Medicine 2001 Feb;134(4):274-81.

192. Young DW. Improving the Consistency with which Investigations are Requested. Medical Informatics 1981;6(1):13-7.

193. Ong RSG, Post J, van Rooij H, et al. Call-duration and triage decisions in out of hours cooperatives with and without the use of an expert system. BMC Family Practice 2008 Feb;9.

194. Dowding D, Mitchell N, Randell R, et al. Nurses' use of computerised clinical decision support systems: a case site analysis. Journal of Clinical Nursing 2009 Apr;18(8):1159-67.

195. Bindels R, Hasman A, Kester AD, et al. The efficacy of an automated feedback system for general practitioners. Informatics in Primary Care 2003(11):69-74.

196. Rosenberg SN, Shnaiden TL, Wegh AA, et al. Supporting the Patient's Role in Guideline Compliance: A Controlled Study. American Journal of Managed Care 2008 Nov;14(11):737-44.

197. Shiffman RN, Liaw Y, Brandt CA, et al. Computer-based guideline implementation systems: A systematic review of functionality and effectiveness. Journal of the American Medical Informatics Association 1999 Mar-Apr;6(2):104-14.

198. McDonald CJ, Wilson GA, McCabe GP. Physician Response to Computer Reminders. Jama-Journal of the American Medical Association 1980;244(14):1579-81.

199. Andre B, Ringdal GI, Loge JH, et al. Experiences with the Implementation of Computerized Tools in Health Care Units: A Review Article. International Journal of Human-Computer Interaction 2008;24(8):753-75.

200. Yusof MM, Papazafeiropoulou A, Paul RJ, et al. Investigating evaluation frameworks for health information systems. International Journal of Medical Informatics 2008 Jun;77(6):377-85.

201. Apkon M, Mattera JA, Lin ZQ, et al. A randomized outpatient trial of a decision-support information technology tool. Archives of Internal Medicine 2005 Nov;165(20):2388-94.

202. Berlin A, Sorani M, Sim I. A taxonomic description of computer-based clinical decision support systems. Journal of Biomedical Informatics 2006 Dec;39(6):656-67.

203. Garg AX, Adhikari NKJ, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes - A

systematic review. JAMA-Journal of the American Medical Association 2005 Mar;293(10):1223-38.

204. Hunt DL, Haynes RB, Hanna SE, et al. Effects of computer-based clinical decision support systems on physician performance and patient outcomes - A systematic review. JAMA-Journal of the American Medical Association 1998 Oct;280(15):1339-46.

205. Kaplan B. Evaluating informatics applications - clinical decision support systems literature review. International Journal of Medical Informatics 2001 Nov;64(1):15-37.

206. Kawamoto K, Houlihan CA, Balas EA, et al. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. British Medical Journal 2005 Apr;330(7494):765-8E.

207. Mayo-Smith MF, Agrawal A. Factors associated with improved completion of computerized clinical reminders across a large healthcare system. International Journal of Medical Informatics 2007 Oct;76(10):710-6.

208. Shojania K, Jennings, A, Mayhew, A, Ramsay, CR, Eccles, MP, and Grimshaw, J. The effects of on-screen, point of care computer reminders on processes and outcomes of care. Cochrane Database of Systematic Reviews 2009;3.

209. Sittig DF, Krall MA, Dykstra RH, et al. A survey of factors affecting clinician acceptance of clinical decision support. BMC Medical Informatics and Decision Making 2006;6:6.

210. Patient Centered Primary Care Collaborative. The Patient-Centered Medical Home: A Purchase Guide - Understanding the model and taking action. Washington DC: Patient Centered Primary Care Collaborative; 2008.

211. Nutting PA, Miller WL, Crabtree BF, et al. Initial Lessons From the First National Demonstration Project on Practice Transformation to a Patient-Centered Medical Home. Annals of Family Medicine 2009;7(3):254-60.

212. Fernandopulle R, Patel N. How the electronic health record did not measure up to the demands of our medical home practice. Health Affairs 2010;29(4):622-8.

213. Andriole KP. Productivity and cost assessment of computed radiography, digital radiography, and screen-film for outpatient chest examinations. Journal of Digital Imaging 2002;15(3):161-9.

214. Mehta AR, Wakefield DS, Kienzle MG, et al. Pediatric tele-echocardiography: evaluation of transmission modalities. Telemedicine Journal and e-Health 2001 Spring;7(1):17-25.

215. Simon SR, Smith DH, Feldstein AC, et al. Computerized prescribing alerts and group academic detailing to reduce the use of potentially inappropriate medications in older people. Journal of the American Geriatrics Society 2006 Jun;54(6):963-8.

216. Balas EA, Austin SM, Mitchell JA, et al. The clinical value of computerized information services - A review of 98 randomized clinical trials. Archives of Family Medicine 1996 May;5(5):271-8.

217. Sintchenko V, Magrabi F, Tipper S. Are we measuring the right end-points? Variables that affect the impact of computerised decision support on patient outcomes: A systematic review. Medical Informatics and the Internet in Medicine 2007 Sep;32(3):225-40.

218. Kastner M, Straus SE. Clinical Decision Support Tools for Osteoporosis Disease Management: A Systematic Review of Randomized Controlled Trials. Journal of General Internal Medicine 2008 Dec;23(12):2095-105.

219. Balas EA, Weingarten S, Garb CT, et al. Improving preventive care by prompting physicians. Archives of Internal Medicine 2000 Feb;160(3):301-8.

220. Bennett JW, Glasziou PP. Computerised reminders and feedback in medication management: a systematic review of randomised controlled trials. Medical Journal of Australia 2003 Mar;178(5):217-23.

221. Hulscher M, Wensing M, Grol R, et al. Interventions to improve the delivery of preventive services in primary care. American Journal of Public Health 1999 May;89(5):737-46.

222. Lu CY, Ross-Degnan D, Soumerai SB, et al. Interventions designed to improve the quality and efficiency of medication use in managed care: A critical review of the literature - 2001-2007. BMC Health Services Research 2008 Apr;8.

223. Grimshaw JM, Thomas RE, MacLennan G, et al. Effectiveness and efficiency of guideline dissemination and implementation strategies. Health Technology Assessment 2004 Feb;8(6):144-50.

224. Johnston ME, Langton KB, Haynes B, et al. Effects of Computer-based Clinical Decision Support Systems on Clinician Performance and Patient Outcome. Annals of Internal Medicine 1994;120(2):135.

225. Bonevski B, Sanson-Fisher RW, Campbell E, et al. Randomized controlled trial of a computer strategy to increase general practitioner preventive care. Preventive Medicine 1999 Dec;29(6):478-86.

226. Morgan M, Goodson J, Barnett G. Long-term changes in compliance with clinical guidelines through computer-based reminders. AMIA Symposium; 1998; Orlando: American Medical Informatics Association; 1998. p. 493.

227. McPhee SJ, Bird JA, Fordham D, et al. Promoting Cancer Prevention Activities by Primary Care Physicians - Results of a Randomized, Controlled Trial. JAMA-Journal of the American Medical Association 1991 Jul;266(4):538-44.

228. Ornstein SM, Garr DR, Jenkins RG, et al. Computer-Generated Physician and Patient Reminders - Tools to Improve Population Adherence to Selected Preventative Services. Journal of Family Practice 1991 Jan;32(1):82-90.

229. Rosser WW, McDowell I, Newell C. Use of Reminders for Preventative Procedures in Family Medicine. Canadian Medical Association Journal 1991 Oct;145(7):807-&.

230. Turner BJ, Day SC, Borenstein B. A Controlled Trial to Improve Delivery of Preventative Care - Physician or Patient Reminders. Journal of General Internal Medicine 1989 Sep-Oct;4(5):403-9.

231. Chambers CV, Balaban DJ, Carlson BL, et al. Microcomputer-generated reminders: Improving the Compliance of Primary Care Physicians with Mammography Screening Guidelines Journal of Family Practice 1989 Sep;29(3):273-80.

232. Gimotty PA, Burack RC, George JA. Delivery of preventive health services for breast cancer control: A longitudinal view of a randomized controlled trial. Health Services Research 2002 Feb;37(1):65-85.

233. Bertoni AG, Bonds DE, Chen HY, et al. Impact of a Multifaceted Intervention on Cholesterol Management in Primary Care Practices Guideline Adherence for Heart Health Randomized Trial. Archives of Internal Medicine 2009 Apr;169(7):678-86.

234. Shiffman RN, Freudigman KA, Brandt CA, et al. A guideline implementation system using handheld computers for office management of asthma: Effects on adherence and patient outcomes. Pediatrics 2000 Apr;105(4):767-73.

235. Safran C, Rind DM, Davis RB, et al. Guidelines for Management of HIV-Infection with Computer-Based Patients Record. Lancet 1995 Aug;346(8971):341-6.

236. Steele A, Eisert S, Davidson A, et al. Using computerized clinical decision support for latent tuberculosis infection screening. American Journal of Preventive Medicine 2005;28(3):281-4.

237. Feldstein A, Elmer P, Smith D, et al. Electronic medical record reminder improves osteoporosis management after a fracture: a randomized, controlled trial. Journal of the American Geriatrics Society 2006;54(3):450-7.

238. Frances CD, Alperin P, Adler JS, et al. Does a fixed physician reminder system improve the care of patients with coronary artery disease? A randomized controlled trial. Western Journal of Medicine 2001 Sep;175(3):165-6.

239. Rossi RA, Every NR. A computerized intervention to decrease the use of calcium channel blockers in hypertension. Journal of General Internal Medicine 1997 Nov;12(11):672-8.

240. Barnett GO, Winickoff RN, Morgan MM, et al. A Computer-Based Monitoring-System for Follow-Up of Elevated Blood Pressure Medical Care 1983;21(4):400-9.

241. Bassa A, del Val M, Cobos A, et al. Impact of a clinical decision support system on the management of patients with hypercholesterolemia in the primary healthcare setting. Disease Management and Health Outcomes 2005(14):258-63.

242. Mitchell E, Sullivan F, Grimshaw JM, et al. Improving management of hypertension in general practice: a randomised controlled trial of feedback derived from electronic patient data. British Journal of General Practice 2005 Feb;55(511):94-101.

243. Montgomery AA, Fahey T, Peters TJ, et al. Evaluation of computer based clinical decision support system and risk chart for management of hypertension in primary care: randomised controlled trial. British Medical Journal 2000 Mar;320(7236):686-90.

244. Cleveringa FGW, Gorter KJ, van den Donk M, et al. Combined Task Delegation, Computerized Decision Support, and Feedback Improve Cardiovascular Risk for Type 2 Diabetic Patients A cluster randomized trial in primary care. Diabetes Care 2008 Dec;31(12):2273-5.

245. Wells S, Furness S, Rafter N, et al. Integrated electronic decision support increases cardiovascular disease risk assessment four fold in routine primary care practice. European Journal of Cardiovascular Prevention & Rehabilitation 2008 Apr;15(2):173-8.

246. Davis RL, Wright J, Chalmers F, et al. A cluster randomized clinical trial to improve prescribing patterns in ambulatory pediatrics. PLoS Clinical Trials 2007 May;2(5).

247. Grant RW, Wald JS, Schnipper JL, et al. Practice-linked online personal health records for type 2 diabetes mellitus - A randomized controlled trial. Archives of Internal Medicine 2008 Sep;168(16):1776-82.

248. Filippi A, Sabatini A, Badioli L, et al. Effects of an automated electronic reminder in changing the antiplatelet drug-prescribing behavior among Italian general practitioners in diabetic patients - An intervention trial. Diabetes Care 2003 May;26(5):1497-500.

249. Tamblyn R, Huang A, Kawasumi Y, et al. The development and evaluation of an integrated electronic prescribing and drug management system for primary care. Journal of the American Medical Informatics Association 2006 Mar-Apr;13(2):148-59.

250. Berner ES, Houston TK, Ray MN, et al. Improving ambulatory prescribing safety with a handheld decision support system: A randomized controlled trail. Journal of the American Medical Informatics Association 2006 Mar-Apr;13(2):171-9.

251. Gerard MN, Tick WE, Das K, et al. Use of Clinical Decision Support to Increase Influenza Vaccination: Multi-year Evolution of the System. Journal of the

American Medical Informatics Association 2008 Nov-Dec;15(6):776-9.

252. Tang PC, LaRosa MP, Newcomb C, et al. Measuring the effects of reminders for outpatient influenza immunizations at the point of clinical opportunity. Journal of the American Medical Informatics Association 1999 Mar-Apr;6(2):115-21.

253. Fiks AG, Grundmeier RW, Biggs LM, et al. Impact of clinical alerts within an electronic health record on routine childhood immunization in an urban pediatric population. Pediatrics 2007 Oct;120(4):707-14.

254. Goetz MB, Hoang T, Bowman C, et al. A system-wide intervention to improve HIV testing in the Veterans Health Administration. Journal of General Internal Medicine 2008 Aug;23(8):1200-7.

255. Tierney WM, McDonald CJ, Hui SL, et al. Computer-Predictions of Abnormal Test-Results - Effects on Outpatient Testing. JAMA-Journal of the American Medical Association 1988 Feb;259(8):1194-8.

256. Collin S, Reeves BC, Hendy J, et al. Implementation of computerised physician order entry (CPOE) and picture archiving and communication systems (PACS) in the NHS: quantitative before and after study. British Medical Journal 2008 Sep;337(7670).

257. Bergmo TS. An economic analysis of teleconsultation in otorhinolaryngology. Journal of Telemedicine and Telecare 1997 December 1, 1997;3(4):194-9.

258. Chua R, Craig J, Esmonde T, et al. Telemedicine for new neurological outpatients: putting a randomized controlled trial in the context of everyday practice. Journal of Telemedicine and Telecare 2002;8(5):270-3.

259. Harno KSR. Telemedicine in managing demand for secondary-care services. Journal of Telemedicine and Telecare 1999 July 6, 1999;5(3):189-92.

260. Jacklin PB, Roberts JA, Wallace P, et al. Virtual outreach: economic evaluation of joint teleconsultations for patients referred by their general practitioner for a specialist opinion. British Medical Journal 2003 Jul;327(7406):84-8A.

261. McIntosh WA, Alston LT, Booher JR, et al. Time spent with patients and charges to patients for specialty consultations using telemedicine. Telemedicine Journal and e-Health 2003 Winter;9(4):345-50.

262. Fortney JC, Pyne JM, Edlund MJ, et al. Design and implementation of the Telemedicine-Enhanced Antidepressant Management study. General Hospital Psychiatry 2006 2006 Jan-Feb;28(1):18-26.

263. Hunkeler E, Meresman J, Hargreaves W, et al. Efficacy of nurse telehealth care and peer support in augmenting treatment of depression in primary care. Archives of Family Medicine 2000;9(8):700.

264. Johnston B, Weeler L, Deuser J, et al. Outcomes of the Kaiser Permanente tele-home health research project. Archives of Family Medicine 2000;9(1):40.

265. Lusignan SD, Althans A, Wells S, et al. A pilot study of radiotelemetry for continuous cardiopulmonary monitoring of patients at home. Journal of Telemedicine and Telecare 2000 February 10, 2000;6(suppl_1):119-22.

266. Rogers M, Small D, Buchan D, et al. Home monitoring service improves mean arterial pressure in patients with essential hypertension A randomized, controlled trial. Annals of Internal Medicine 2001;134(11):1024-32.

267. Scalvini S, Zanelli E, Conti C, et al. Assessment of prehospital chest pain using telecardiology. Journal of Telemedicine and Telecare 2002 August 1, 2002;8(4):231-6.

268. Cusack CM, Byrne CM, Hook JM, et al. Health information technology evaluation toolkit. [PDF] 2009 [cited 2010 May 2010]; Available from: http://healthit.ahrq.gov/portal/server.pt/gateway/PTARGS_0_1248_875888_0_0_18/09_0083_EF.pdf

269. Canada Health Infoway. Canada health infoway benefits evaluation indicators technical report. 2006 [cited 2010 May 2010]; Available from: http://www2.infoway-inforoute.ca/Documents/BE%20Techical%20Report%20%28EN%29.pdf

270. MASSPRO. A systems approach to operational redesign workbook. [cited 2010 May 2010]; Available from: http://www.masspro.org/HIT/PFQ/docs/tools/DOQIT%20WB%20for%20WEB.pdf

271. Backer LA. Strategies for better patient flow and cycle time. Family Practice Management 2002 June;9(6):45-50.

272. Carter JH, editor. Electronic health records, 2nd edition. Philadelphia: American College of Physicians; 2001.

273. American Medical Association. A clinician's guide to electronic prescribing. 2008 [cited 2010 May 2010]; Available from: http://www.ama-assn.org/ama1/pub/upload/mm/472/electronic-e-prescribing.pdf

274. HIMSS EHR Usability Task Force. Defining and testing EMR usability: Principles and proposed methods of EMR usability evaluation and rating. 2009 [cited 2010 May 2010]; Available from: http://www.himss.org/content/files/HIMSS_DefiningandTestingEMRUsability.pdf

275. HIMSS Ambulatory Paperless Clinics Work Group. EHR Implementation in Ambulatory Care; 2007.

276. Houck S. What works: Effective tools and case studies to improve clinical office practice. Boulder, CO: HealthPress Publishing; 2004.

277. Daniel D, Lohman P. Think lean: Redesign workflow to adopt EHR. MGMA Connexion 2007;7(1):17-8.

278. Goroll AH, Simon SR, Tripathi M, et al. Community-wide implementation of health information technology: The Massachusetts eHealth Collaborative experience. Journal of the American Medical Informatics Association 2009 January 2009;16(1):132-9.

279. Mostashari F, Tripathi M, Kendall M. A tale of two large community electronic health record extension projects. Health Affairs 2009 Mar-Apr;28(2):345-56.

280. Tripathi M, Delano D, Lund B, et al. Engaging patients for health information exchange. Health Affairs 2009 March 1, 2009;28(2):435-43.

281. Wright A, Soran C, Jenter CA, et al. Physician attitudes toward health information exchange: Results of a statewide survey. Journal of the American Medical Informatics Association January 2010;17(1):66-70.

282. The New York City Department of Health and Mental Hygiene. Electronic health records for the primary care provider. City Health Information 2007;26(1):1-6.

283. Babbitt N. In record time: Diary of an EMR installation. Health Management Technology 2003;24(2):28-30.

284. Baron RJ. What's keeping us so busy in primary care? A snapshot from one practice. The New England Journal of Medicine 2010;362(17):1632-6.

285. Beeler A. Response to request for information by Dr. Angela Beeler of South County Pediatrics on July 6, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-3.

286. Berman H. Response to request for information by Heidi Berman of an unidentified EMR reseller on August 24, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-3.

287. Chapman L. EHR supports healthier patients and a healthier bottom line. 2009 [cited 2010 February 16]; Available from: http://psqh.com/julyaugust-2009/168-ehr-supports-healthier-patients.html

288. Fullerton C, Aponte P, Hopkins R, III, et al. Lessons learned from pilot site implementation of an ambulatory electronic health record. Baylor University Medical Center Proceedings 2006;19(4):303-9.

289. Lamberts R. Electronic health record in Evans Medical Group. 2003 [cited 2009 November 11]; Available from: http://www.himss.org/content/files/davies_2003_primarycare_evans.pdf

290. Lester WT, Ashburner JM, Grant RW, et al. Mammography FastTrack: An intervention to facilitate reminders for breast cancer screening across a heterogeneous multi-clinic primary care network. Journal of the American Medical Informatics Association 2009;16(2):187-95.

291. Mohr T. The second time around. Health Management Technology 2008;29(9):22-5.

292. Morrow J. Davies recognition program: Independent primary care practices - North Fulton Family Medicine. 2004 [cited 2009 November 11]; Available from: http://www.himss.org/content/files/davies2004_primarycare_northFulton.pdf

293. Murphy JA, Ahlstrom JS. Nursing process redesign with the implementation of a computer based patient record in the ambulatory setting. Studies in Health Technology and Informatics 1997;46:323-9.

294. Neil N. Improving rates of screening and prevention by leveraging existing information systems. Joint Commission Journal on Quality and Safety 2003 Nov;29(11):610-8.

295. Tang P, Jaworski M, Fellencer C, et al. Methods for assessing information needs of clinicians in ambulatory care. Nineteenth Annual Symposium on Computer Applications in Medical Care; 1995; Philadelphia, PA; 1995. p. 630-4.

296. Zind B. Response to request for information by Barbara Zind of an unidentified family practice on August 3, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-2.

297. Goud R, Jaspers MW, Hasman A, et al. Subjective usability of the CARDSS guideline-based decision support system. Studies in Health Technology and Informatics 2008;136:193-8.

298. Häkkinen H, Korpela M. A participatory assessment of IS integration needs in maternity clinics using activity theory. International Journal of Medical Informatics 2007 Nov-Dec;76(11-12):843-9.

299. Unertl KM, Weinger M, Johnson K. Variation in use of Informatics tools among providers in a diabetes clinic. AMIA Annual Symposium Proceedings; 2007: AMIA; 2007. p. 756-60.

300. Unertl KM, Weinger MB, Johnson KB. Applying direct observation to model workflow and assess adoption. AMIA Annual Symposium Proceedings 2006:794-8.

301. Johnson K, FitzHenry F. Case report: Activity diagrams for integrating electronic prescribing tools into clinical workflow. Journal of the American Medical Informatics Association 2006 Jul-Aug;13(4):391-5.

302. Khoury A. Support of quality and business goals by an ambulatory automated medical record system in Kaiser Permanente of Ohio. Effective Clinical Practice 1998;1(2):73-82.

303. Zai A, Grant R, Estey G, et al. Lessons from implementing a combined workflow-informaties system for diabetes management. Journal of the American Medical Informatics Association 2007 Nov 10-14;15(4):524-33.

304. Stanton N, Salmon P, Walker G, et al. Human Factors Methods: A Practical Guide for Engineering and Design. Great Britain: Ashgate; 2005.

305. Unertl KM, Novak LL, Johnson KB, et al. Traversing the many paths of workflow research: Developing a conceptual framework of workflow terminology through a systematic literature review. Journal of the American Medical Informatics Association 2010;17:265-73.

306. Talmon J, Ammenwerth E, Brender J, et al. STARE-HI - Statement on reporting of evaluation studies in Health Informatics. International Journal of Medical Informatics 2009 Jan;78(1):1-9.

307. Karsh BT, Beasley JW, Hagenauer ME. Are electronic medical records associated with improved perceptions of the quality of medical records, working conditions, or quality of working life? Behaviour & Information Technology 2004 Sep-Oct;23(5):327-35.

308. Karsh B-T. Beyond usability: designing effective technology implementation systems to promote patient safety. Quality and Safety in Health Care 2004;13:388-94.

Appendix A: Technical Expert Panel

David Classen, M.D., M.S.
Senior Partner, CSC Healthcare
Associate Professor, University of Utah School of Medicine

Sarah Corley, M.D.
Chief Medical Officer
NextGen Healthcare Information Systems, Inc.

Jeffrey P. Friedman, M.D., F.A.C.P.
Clinical Associate Professor of Medicine, New York University School of Medicine
Co-founder of Murray Hill Medical Group

David R. Hunt, M.D., F.A.C.S.
Chief Medical Officer
Office of the National Coordinator for Health IT

Robert M. Tennant, M.A.
Senior Policy Advisor
Medical Group Management Association

Steven E. Waldren, M.D., M.S.
Director, Center for Health Information Technology
American Academy of Family Physicians

Appendix B: Relevant Systematic Literature Reviews

Ash JS, Stavri PZ, Kuperman GJ. A consensus statement on considerations for a successful CPOE implementation. J Am Med Inform Assoc 2003 May-Jun;10(3):229-34.

Bennett JW, Glasziou PP. Computerised reminders and feedback in medication management: a systematic review of randomised controlled trials. Med J Aust 2003 Mar;178(5):217-2.

Chaudhry B, Wang J, Wu SY, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med 2006 May;144(10):742-52.

Dexheimer JW, Talbot TR, Sanders DL, et al. Prompting clinicians about preventive care measures: A systematic review of randomized controlled trials. 2005 Oct; Washington, DC; 2005. p. 311-20.

Eslami S, Abu-Hanna A, de Keizer NF. Evaluation of outpatient computerized physician medication order entry systems: a systematic review. J Am Med Inform Assoc 2007;14(4):400-6.

Garg AX, Adhikari NKJ, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes—a systematic review. JAMA 2005 Mar;293(10):1223-38.

Hersh W, Helfand M, Wallace J, et al. A systematic review of the efficacy of telemedicine for making diagnostic and management decisions. J Telemed Telecare 2002 August 1, 2002;8(4):197-209.

Hersh WR, Hickam DH, Severance SM, et al. Diagnosis, access and outcomes: update of a systematic review of telemedicine services. J Telemed Telecare 2006;12:3-31.

Kaplan B. Evaluating informatics applications—some alternative approaches: theory, social interactionism, and call for methodological pluralism. Int J Med Inform 2001 Nov;64(1):39-55.

Kawamoto K, Houlihan CA, Balas EA, et al. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. Br Med J 2005 Apr;330(7494):765-8E.

Mitchell E, Sullivan F. A descriptive feast but an evaluative famine: systematic review of published articles on primary care computing during 1980-97. Br Med J 2001 Feb;322(7281):279-82E.

Mollon B, Chong JJR, Holbrook AM, et al. Features predicting the success of computerized decision support for prescribing: a systematic review of randomized controlled trials. BMC Med Inform Decis Mak 2009 Feb;9.

Appendix C: Organizations and Associations Reviewed

	Organization/Association	Web site
1	American Academy of Family Physicians: The Center for Health IT (AAFP)	http://www.aafp.org/online/en/home.html http://www.centerforhit.org/online/chit/home.html
2	American Academy of Pediatrics (AAP)	http://www.aap.org/
3	Affinity Health System	http://www.affinityhealth.org/
4	American Health Information Management Association (AHIMA)	http://www.ahima.org/
5	Agency for Healthcare Research and Quality—Health IT Initiative	http://www.ahrq.gov/ http://healthit.ahrq.gov
6	Ambulatory Pediatric Association (APA) or Academic Pediatric Association	http://www.ambpeds.org/
7	American College of Physicians (ACP)	http://www.acponline.org/
8	American Health Quality Association (AHQA)	http://www.ahqa.org/
9	American Medical Association (AMA)	http://www.ama-assn.org/
10	American Medical Group Association (AMGA)	http://www.amga.org/
11	American Medical Informatics Association (AMIA)	https://www.amia.org/
12	American Nurses Association	http://www.nursingworld.org/
13	American Nursing Informatics Association (ANIA)	http://www.ania-caring.org/
14	American Osteopathic Association	http://www.osteopathic.org/
15	American Physical Therapy Association (APTA)	http://www.apta.org/
16	American Society for Quality (ASQ)	http://www.asq.org/
17	American Society of Health System Pharmacists	http://www.ashp.org/
18	Association of Medical Directors of Information Systems (AMDIS)	http://www.amdis.org/
19	Association of Primary Care Physicians (APCP)	http://www.apcpky.com/
20	Aurora UW Medical Group	http://www.aurorahealthcare.org/facilities/display.asp?ID=0036&Kind=Clinic
21	Bridges to Excellence	http://www.bridgestoexcellence.org/
22	The Boeing Company	http://www.boeing.com/
23	California Healthcare Foundation	http://www.chcf.org/
24	Carnegie Mellon Center for Computational Analysis of Social and Organizational Systems (CASOS)	http://www.casos.cs.cmu.edu/
25	The Center for Improving Medication Management	http://www.thecimm.org/
26	Centers for Medicare and Medicaid Services (CMS)	http://www.cms.hhs.gov/
27	Certification Commission for Healthcare Information Technology (CCHIT)	http://www.cchit.org/
28	Coleman Associates	http://www.patientvisitredesign.com/
29	Colorado Foundation for Medical Care	http://www.cfmc.org/
30	Colorado Health Foundation	http://www.coloradohealth.org/
31	Cooley Dickinson Hospital	http://www.cooley-dickinson.org/
32	Department of Biomedical Informatics, U of Utah	http://www.bmi.utah.edu/
33	eHealth Initiative	http://www.ehealthinitiative.org/
34	Enhydra	http://www.enhydra.org/
35	Health Affairs	http://www.healthaffairs.org/
36	Healthcare Information and Management Systems Society (HIMSS)	http://www.himss.org/
37	The Hiser Group	http://www.hiser.com.au/
38	Human Factors and Ergonomics Society: Healthcare Technical Group (HFES TG)	http://www.hfes.org/web/TechnicalGroups/technical.html
39	Illinois Foundation for Quality HealthCare (IFQHC)	http://www.ifqhc.org/
40	Improving Performance In Practice Program–Michigan group (MI IPIP)	http://ipip.aiag.org/
41	Institute for Operations Research and the Management Sciences (INFORMS) Online	http://www.informs.org/
42	InfoSys Technologies, Ltd.	http://www.infosys.com/
43	Institute for Healthcare Improvement (IHI)	http://www.ihi.org/ihi
44	Institute for Safe Medication Practices (ISMP)	http://www.ismp.org/

	Organization/Association	Web site
45	Institute of Industrial Engineering (IIE)	http://www.iienet2.org/
46	Internet Center for Management and Business Administration, Inc.	http://www.netmba.com/site/about/
47	Iowa Foundation for Medical Care (IFMC)	http://www.ifmc.org/
48	Kaiser Permanente	https://www.kaiserpermanente.org/
49	MA eHealth Collaborative	http://www.maehc.org/
50	Margaret\A Consulting, LLC	http://www.margret-a.com/
51	Markle Foundation	http://www.markle.org/
52	Marshfield Clinic Research Foundation	http://www.marshfieldclinic.org/research/
53	Massachusetts General Hospital	http://www.massgeneral.org/
54	Masspro	http://www.masspro.org/
55	Medical College of Wisconsin (MCW)	http://www.mcw.edu/
56	Medical Connectivity Consulting	http://medicalconnectivity.com/
57	Medical Group Management Association (MGMA)	http://www.mgma.com/
58	MedTrak	http://www.medtraksystems.com/
59	MetaStar	http://www.metastar.com/
60	Mind Tools Ltd	http://www.mindtools.com/
61	MPRO, the Medicare Quality Improvement Organization for Michigan	http://www.mpro.org/
62	Mycoted	http://www.mycoted.com/
63	National Alliance for Primary Care Informatics	N/A
64	National Committee for Quality Assurance	http://www.ncqa.org/
65	New York Primary Care Information Project (PCIP)	http://www.nyc.gov/html/doh/html/pcip/pcip.shtml
66	The New York Times	http://www.nytimes.com/
67	Office of the National Coordinator for Health Information Technology (ONC)	http://healthit.hhs.gov/
68	Patient-Centered Primary Care Collaborative	http://www.pcpcc.net/
69	Perot Systems	http://www.perotsystems.com/
70	Physicians EHR, Inc.	http://www.physiciansehr.org/
71	Siemens Medical Solutions USA	http://www.medical.siemens.com/
72	Society for Health Systems (SHS)	http://www.iienet.org/SHS/
73	Society of General Internal Medicine	http://www.sgim.org/
74	Southern California Evidence-based Practice Center (EPC)	http://www.rand.org/health/centers/epc/
75	St. Mary's Outpatient Center	http://www.deancare.com/doctors-locations/clinic/dean-clinic-profile.aspx?id=60914
76	Surescripts	http://www.surescripts.com
77	UMass Memorial Health Care	http://www.umassmemorial.org/
78	United Physicians (UP)	http://www.updoctors.com/
79	University HealthSystem Consortium	https://www.uhc.edu/
80	University Research Co., LLC	http://www.urc-chs.com/
81	Upstate Neurology (via MGMA)	http://www.upstateneurology.com/
82	UW Health	http://www.uwhealth.org/
83	W.K. Kellogg Foundation	http://www.wkkf.org/
84	Westat	http://www.westat.com/
85	Wisconsin Collaborative for Healthcare Quality (includes IPIP program)	http://www.wchq.org/
86	Wisconsin Medical Society (WMS)	http://www.wisconsinmedicalsociety.org/
87	Wisconsin Research and Education Network (WREN)	http://www.fammed.wisc.edu/research/wren/

Appendix D: User Story References (including those identified in the literature review)

Babbitt N. In record time: Diary of an EMR installation. Health Manag Technol 2003;24(2):28-30.

Baron R, Fabens E, Schiffman M, et al. Electronic health records: Just around the corner? Or over the cliff? Ann Intern Med 2005;143(3):222-6.

Beeler A. Response to request for information by Dr. Angela Beeler of South County Pediatrics on July 6, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-3.

Berman H. Response to request for information by Heidi Berman of an unidentified EMR reseller on August 24, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-3.

Bostrom AC, Schafer P, Dontje K, et al. Electronic health record: implementation across the Michigan Academic Consortium. Comput Inform Nurs 2006 Jan-Feb;24(1):44-52.

Brownbridge G, Fitter M, Sime M. The doctor's use of a computer in the consulting room: An analysis. Int J Man Mach Stud 1984;21(1):65-90.

Byrne JM, Elliott S, Firek A. initial experience with patient-clinician secure messaging at a VA Medical Center. J Am Med Inform Assoc 2009 Mar-Apr;16(2):267-70.

Carayon P, Smith P, Hundt AS, et al. Implementation of an electronic health records system in a small clinic: the viewpoint of clinic staff. Behav Inf Technol 2009 2009 Jan-Feb;28(1):5-20.

Cauldwell M, Beattie C, Cox B, et al. The impact of electronic patient records on workflow in general practice. Health Informatics J 2007;13(2):155-60.

Chapman L. EHR supports healthier patients and a healthier bottom line. 2009. Available at: http://psqh.com/julyaugust-2009/168-ehr-supports-healthier-patients.html. Accessed February 16, 2009.

Crosson JC, Isaacson N, Lancaster D, et al. Variation in electronic prescribing implementation among twelve ambulatory practices. J Gen Intern Med 2007 Apr;23(4):364-71.

Fullerton C, Aponte P, Hopkins R, III, et al. Lessons learned from pilot site implementation of an ambulatory electronic health record. Baylor University Medical Center Proceedings 2006;19(4):303-9.

Goldstein MK, Coleman RW, Tu SW, et al. Translating research into practice: organizational issues in implementing automated decision support for hypertension in three medical centers. J Am Med Inform Assoc 2004 Sep-Oct;11(5):368-76.

Goud R, Jaspers MW, Hasman A, et al. Subjective usability of the CARCDS guideline-based decision support system. Stud Health Technol Inform 2008;136:193-8.

Häkkinen H, Korpela M. A participatory assessment of IS integration needs in maternity clinics using activity theory. Int J Med Inform 2007 Nov-Dec;76(11-12):843-9.

Hollingworth W, Devine EB, Hansen RN, et al. The impact of e-Prescribing on prescriber and staff time in ambulatory care clinics: a time-motion study. J Am Med Inform Assoc 2007;14(6):722-30.

Johnson K, FitzHenry F. Case report: activity diagrams for integrating electronic prescribing tools into clinical workflow. J Am Med Inform Assoc 2006 Jul-Aug;13(4):391-5.

Khoury A. Support of quality and business goals by an ambulatory automated medical record system in Kaiser Permanente of Ohio. Eff Clin Pract 1998;1(2):73-82.

Lamberts R. Electronic health record in Evans Medical Group. 2003. Available at: http://www.himss.org/content/files/davies_2003_primarycare_evans.pdf. Accessed November 11, 2009.

Lester WT, Ashburner JM, Grant RW, et al. Mammography FastTrack: An intervention to facilitate reminders for breast cancer screening across a heterogeneous multi-clinic primary care network. J Am Med Inform Assoc 2009;16(2):187-95.

Lorenzi NM, Kouroubali A, Detmer DE, et al. How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. BMC Med Inform Decis Mak 2009;9:15.

Miller RH, West C, Brown TM, et al. The value of electronic health records in solo or small group practices. Health Aff 2005;24(5):1127.

Mohr T. The second time around. Health Manag Technol 2008;29(9):22-5.

Morris CJ, Cantrill JA, Avery AJ, et al. Preventing drug related morbidity: a process for facilitating changes in practice. Qual Saf Health Care 2006;15(2):116-21.

Morrow J. Davies recognition program: independent primary care practices–North Fulton Family Medicine. 2004. Available at: http://www.himss.org/content/files/davies2004_primarycare_northFulton.pdf. Accessed November 11, 2009.

Murphy JA, Ahlstrom JS. Nursing process redesign with the implementation of a computer based patient record in the ambulatory setting. Stud Health Technol Inform 1997;46:323-9.

Neil N. Improving rates of screening and prevention by leveraging existing information systems. Jt Comm J Qual Saf 2003 Nov;29(11):610-8.

Pluye P, Grad RM. How information retrieval technology may impact on physician practice: an organizational case study in family medicine. J Eval Clin Pract 2004 Aug;10(3):413-30.

Sciamanna CN, Marcus BH, Goldstein MG, et al. Feasibility of incorporating computer-tailored health behaviour communications in primary care settings. Inform Prim Care 2004;12(1):40-8.

Steele AW, Eisert S, Witter J, et al. The effect of automated alerts on provider ordering behavior in an outpatient setting. PLoS Medicine 2005 Sep;2(9):864-70.

Tang P, Jaworski M, Fellencer C, et al. Methods for assessing information needs of clinicians in ambulatory care. Nineteenth Annual Symposium on Computer Applications in Medical Care; 1995; Philadelphia, PA; 1995. p. 630-4.

Toth-Pal E, Wardh I, Strender L-E, et al. Implementing a clinical decision-support system in practice: a qualitative analysis of influencing attitudes and characteristics among general practitioners. Inform Health Soc Care 2008;33(1):39-54.

Unertl KM, Weinger MB, Johnson KB. Applying direct observation to model workflow and assess adoption. AMIA Annual Symposium Proceedings 2006:794-8.

Unertl KM, Weinger MB, Johnson KB. Variation in use of Informatics tools among providers in a diabetes clinic. AMIA Annual Symposium Proceedings; 2007: AMIA; 2007. p. 756-60.

Wogen S, Fulop G, Heller J. Improving the efficiency of the prescription process and promoting plan adherence. Drug Benefit Trends 2003;15(9):35-40.

Zai AH, Grant RW, Estey G, et al. Lessons from implementing a combined workflow-informaties system for diabetes management. 2007 Nov 10-14; Chicago, IL; 2007. p. 524-33.

Zind B. Response to request for information by Barbara Zind of an unidentified family practice on August 3, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-2.

Appendix E: Excluded References

Abboud PA, Ancheta R, McKibben M, et al. Impact of workflow-integrated corollary orders on aminoglycoside monitoring in children. Health Informatics J 2006;12(3):187-98.

Abbrecht PH, Oleary TJ, Behrendt DM. Evaluation of a computer-assisted method for individualised anticoagulation—retrospective and prospective studies with a pharmacodynamic model. Clinical Pharmacology & Therapeutics 1982;32(1):129-36.

ACP Internist. ACP Internist. 2008. Available at: http://www.acpinternist.org/. Accessed July 9, 2009.

Adams J, Culp L, Byron J. Workflow assessment and redesign. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 36-9.

Adams J, Culp L. Staffing and managing implementation teams. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 40-3.

Adler K. Practice profiles on electronic prescribing–Dr. Kenneth Adler. 2009. Available at: http://www.surescripts.com/downloads/PracticeProfiles-Adler.pdf. Accessed November 13, 2009.

Agency for Healthcare Research and Quality. Emerging lessons–Computerized provider order entry–Ambulatory. 2008. Available at: http://healthit.ahrq.gov/portal/server.pt?open=514&objID=5562&mode=2&holderDisplayURL=http://prodportallb.ahrq.gov:7087/publishedcontent/publish/communities/a_e/ahrq_funded_projects/test_emerging_lessons/acpoe/computerized_provider_order_entry___ambulatory.html. Accessed May 20 2009.

Ageno W, Turpie AGG. A randomized comparison of a computer-based dosing program with a manual system to monitor oral anticoagulant therapy. Thromb Res 1998 Sep;91(5):237-40.

AHIMA e-HIM Work Group on EHR Data Content. Guidelines for developing a data dictionary. J AHIMA 2006;77(2):64A-D.

AHIMA e-HIM Work Group on E-mail as a Provider-Patient Electronic Communication Medium and Its Impact on the Electronic Health Record. E-mail as a provider-patient electronic communication medium and its impact on the electronic health record. J AHIMA 2003.

AHIMA e-HIM Work Group on E-mail. E-mail as a provider-patient electronic communication medium and its impact on the electronic health record–Appendix A. J AHIMA 2003.

AHIMA e-HIM Work Group on E-mail. E-mail as a provider-patient electronic communication medium and its impact on the electronic health record–Appendix D: Summary of best practices for provider-patient e-mail communication. J AHIMA 2003.

AHIMA e-HIMTM Task Force. The strategic importance of electronic health records management. J AHIMA 2004;75(9):80A-B.

AHIMA e-HIM™ Work Group on Computer-Assisted Coding. Delving into computer-assisted coding (AHIMA practice brief). J AHIMA 2004;75(10):48A-H.

AHIMA HIM Practice Transformation Work Group. A checklist for assessing HIM department readiness and planning for the EHR. J AHIMA 2005;76(6):56E-H.

AHIMA Work Group on Electronic Health Records Management. The strategic importance of electronic health records management: Checklist for transition to the EHR. J AHIMA 2004;75(9):80C-E.

AHIMA Workgroup on Core Data Sets as Standards for the EHR. E-HIM strategic initiative: Core data sets (AHIMA practice brief). J AHIMA 2004;75(8):68A-D.

Allen J, Blanks G. Practical tools for surgical services. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Allen S. Creating a culture of safety. J Perioper Pract 2007 Jun;17(6):244-6.

Amatayakul M. Marget\A Consulting: strategies for the digital future of healthcare information. 2007. Available at: http://www.margret-a.com/. Accessed May 20, 2009.

American Academy of Family Physicians. The Center for HIT. 2009. Available at: http://www.centerforhit.org/online/chit/home.html. Accessed May 20, 2009.

American College of Physicians. Health information technology. 2009. Available at: http://www.acponline.org/running_practice/technology/. Accessed May 20, 2009.

American Medical Association. AMA–ePrescribing Learning Center. 2009. Available at: http://www.ama-assn.org/ama/pub/eprescribing/home.shtml. Accessed June 19, 2009.

American Medical Association. Clinical quality: Collaborative for performance measure integration with EHR systems. 2009. Available at: http://www.ama-assn.org/ama/pub/physician-resources/clinical-practice-improvement/clinical-quality/collaborative-performance-measure-integration-ehr-systems.shtml. Accessed June 19, 2009.

American Medical Association. Health information technology: Putting health information technology (Health IT) into practice. 2009. Available at: http://www.ama-assn.org/ama/pub/physician-resources/solutions-managing-your-practice/health-information-technology/putting-hit-practice.shtml. Accessed June 19, 2009.

American Medical Association. Physician resources: Tools. 2009. Available at: http://www.ama-assn.org/ama/no-index/physician-resources/16878.shtml. Accessed June 19, 2009.

American Society for Quality. Process analysis tools: Mistake proofing. 2009. Available at: http://www.asq.org/learn-about-quality/process-analysis-tools/overview/mistake-proofing.html. Accessed July 23, 2009.

American Society for Quality. Seven new management and planning tools: Matrix diagram. 2009. Available at: http://www.asq.org/learn-about-quality/new-management-planning-tools/overview/matrix-diagram.html. Accessed July 23, 2009.

Andrews R. Practice profiles on electronic prescribing—Dr. Rebecca Andrews. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Andrews.pdf. Accessed November 13, 2009.

Andriole KP. Productivity and cost assessment of computed radiography, digital radiography, and screen-film for outpatient chest examinations. J Digit Imaging 2002;15(3):161-9.

Androwich I, Hastings C. A practical approach to developing system performance indicators. Nurs Econ 1996 May-Jun;14(3):174-9.

Antonucci YL, Bender AD. The quality and cost of medical care. The potential for information technology to meet the challenge. Med Group Manage J 1998 May-Jun;45(3):12-4, 6-9.

Arnold SR, Straus SE. Interventions to improve antibiotic prescribing practices in ambulatory care. Cochrane Database Syst Rev 2005(4).

Artinian N, Harden J, Kronenberg M, et al. Pilot study of a Web-based compliance monitoring device for patients with congestive heart failure. Heart Lung 2003;32(4):226-33.

Artinian N, Washington O, Templin T. Effects of home telemonitoring and community-based monitoring on blood pressure control in urban African Americans: a pilot study. Heart Lung 2001;30(3):191-9.

Asbury AJ. To computerise or not. Br Med J (Clin Res Ed) 1983 Jun 25;286(6383):2046-9.

Asch SM, McGlynn EA, Hogan MM, et al. Comparison of quality of care for patients in the Veterans Health Administration and patients in a national sample. Ann Intern Med 2004 Dec;141(12):938-45.

Atreja A, Gordon SM, Pollock DA, et al. Opportunities and challenges in utilizing electronic health records for infection surveillance, prevention, and control. American Journal of Infection Control 2008 Apr;36(3):S37-S46.

Augustine K, Holmes III D, Hanson D, et al. Comprehensive, powerful, efficient, intuitive: a new software framework for clinical imaging applications (Proceedings Paper). Progress in Biomedical Optics and Imaging 2006;7(27).

Augustine KE, Holmes DR, III, Hanson DP, et al. Comprehensive, powerful, efficient, intuitive: a new software framework for clinical imaging applications. 2006; USA: SPIE–The International Society for Optical Engineering; 2006. p. 61410-1.

Avorn J, Choudhry NK. Using computer-based decision support to close the "Know-Do" gap in lipid-lowering therapy. Circulation 2008 Jan;117(3):336-7.

Bakken S, Currie LM, Lee NJ, et al. Integrating evidence into clinical information systems for nursing decision support. Int J Med Inform 2008 Jun;77(6):413-20.

Balanced Scorecard Institute. Basic tools for process improvement: Affinity diagram. 2009. Available at: http://www.balancedscorecard.org/Portals/0/PDF/affinity.pdf. Accessed June 22, 2009.

Balas EA, Li ZR, Mitchell JA, et al. A decision-support system for the analysis of clinical-practice patterns. The Annual Symposium on Computer Applications in Medical Care; 1994 Nov 05-09; Washington, DC; 1994. p. 366-70.

Barnett G. The application of computer-based medical-record systems in ambulatory practice. N Engl J Med 1984;310(25):1643-50.

Baron RJ, Fabens EL, Schiffman M, et al. Perspective. Electronic health records: just around the corner? Or over the cliff? Ann Intern Med 2005;143(3):222-6.

Barrett M, Holmes B, McAulay S. Electronic medical records: a buyer's guide for small physician practices. Oakland, CA: California HealthCare Foundation; 2003.

Barth C, Tobman M, Natscher C, et al. Fusing a systematic and a case-based repository for medical decision support. Stud Health Technol Inform 2003;95:560-4.

Barton AJ. Decision support and the clinical nurse specialist. Clin Nurse Spec 2009 Jan-Feb;23(1):9-10.

Bates DW, Kuperman GJ, Rittenberg E, et al. A randomized trial of a computer-based intervention to reduce utilization of redundant laboratory tests. Am J Med 1999 Feb;106(2):144-50.

Bates DW. Drugs and adverse drug reactions—How worried should we be? JAMA 1998 Apr;279(15):1216-7.

Bauer C, Bozard C. Health information exchanges case history. Leveling the playing field. How one health system competes with a national reference lab for outpatient lab services revenue. Health Manag Technol 2009 Feb;30(2):14-5, 30.

Baxter GD, Monk AF, Tan K, et al. Using cognitive task analysis to facilitate the integration of decision support systems into the neonatal intensive care unit. Artif Intell Med 2005;35(3):243-57.

Bayegan E, Tu S. The helpful patient record system: problem oriented and knowledge based. Proc AMIA Symp 2002:36-40.

Begg C, Cho M, Eastwood S, et al. Improving the quality of reporting of randomized controlled trials–The CONSORT statement. JAMA 1996 Aug;276(8):637-9.

Begg EJ, Atkinson HC, Jeffery GM, et al. Individualized aminoglycoside dosage based on pharmacokinetic analysis is superior to dosage based on physician intuition at achieving target plasma drug concentrations. Br J Clin Pharmacol 1989 Aug;28(2):137-41.

Beilby JJ, Duszynski AJ, Wilson A, et al. Electronic decision support systems at point of care: trusting the deus ex machina. Med J Aust 2005 Jul;183(2):99-100.

Bell DS, Cretin S, Marken RS, et al. A conceptual framework for evaluating outpatient electronic prescribing systems based on their functional capabilities. J Am Med Inform Assoc 2004 Jan-Feb;11(1):60-70.

Beller SE, Monatesti SJ. Tactic–Use evolving health information technology tools. 2009. Available at: http://wellness.wikispaces.com/Tactic+-+Use+Evolving+Health+Information+Technology+Tools. Accessed May 20, 2009

Belson D, Dessouky M, Hall R, et al. Methodologies to improve patient flow. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Benatar D, Bondmass M, Ghitelman J, et al. Outcomes of chronic heart failure. Am Med Assoc; 2003. p. 347-52.

Benedetto AR. Adapting manufacturing-based Six Sigma methodology to the service environment of a radiology film library. J Healthc Manag 2003;48(4):263-80.

Benneyan JC. An introduction to using computer simulation in healthcare: patient wait case study. J Soc Health Syst 1997;5(3):1-15.

Benson S. Computer-assisted coding software improves documentation, coding, compliance, and revenue. Perspect Health Inf Manag 2006.

Benussi G, Matthews LH, Daris F, et al. Improving patient flow in ambulatory care through computerized evaluation techniques. Rev Epidemiol Sante Publique 1990;38(3):221-6.

Berg M, Toussaint P. The mantra of modeling and the forgotten powers of paper: a sociotechnical view on the development of process-oriented ICT in health care. 2002 Apr 10; Heidelberg, Germany; 2002. p. 223-34.

Bergeson SC, Dean JD. A systems approach to patient-centered care. JAMA 2006 Dec 20;296(23):2848-51.

Bergmo TS. An economic analysis of teleconsultation in otorhinolaryngology. J Telemed Telecare 1997 December 1, 1997;3(4):194-9.

Berntsen KJ. Implementation of patient centeredness to enhance patient safety. J Nurs Care Qual 2006 Jan-Mar;21(1):15-9.

Beuscart-Zéphir M, Anceaux F, Renard J. Integrating users' activity analysis in the design and assessment of medical software applications: the example of anesthesia. In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 234-8.

Beuscart-Zephir MC, Pelayo S, Anceaux F, et al. Impact of CPOE on doctor-nurse cooperation for the medication ordering and administration process. Int J Med Inform 2005 Aug;74(7-8):629-41.

Blair D, Schutte PC. The electronic medical record in multi-site family practice. Part II: The implementation phase. J Med Pract Manage 2003 Nov-Dec;19(3):131-6.

Bobis KG, Camoriano J. Managing technology in a physician-led organization. J Healthc Inf Manag 2003 Spring;17(2):24-31.

Bodenheimer T. Primary care in the United States—innovations in primary care in the United States. Br Med J 2003 Apr;326(7393):796-8.

Bogar S. Improving patient throughput: growing organizational capacity through project management and process improvement. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Bondmass M, Bolger N, Castro G, et al. The effect of home monitoring and telemanagement on blood pressure control among African Americans. Telemed J 2000;6(1):15-23.

Bonnabry P, Despont-Gros C, Grauser D, et al. A risk analysis method to evaluate the impact of a computerized provider order entry system on patient safety. J Am Med Inform Assoc 2008 Jul-Aug;15(4):453-60.

Boyer E, Adams J, Barnes D. System integration. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 89-94.

Boyer E, Soback M. Production support. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 95-100.

Brandon R, Myers L. Clinical Microsystems—an industrial engineering perspective. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Brebner J, Brebner E, Ruddick-Bracken H. implementation of telemedicine services. J Telemed Telecare 2005;11(1):3-5.

Brender J. Evaluation of health information applications in a lifecycle perspective. In: Blobel B, Gell G, Hildebrand C, et al., editors. Contribution of medical informatics to health: integrated clinical data and knowledge to support primary, secondary, tertiary and home care. Berlin: Akademische Verlagsgesellschaft Aka GmbH; 2004. p. 7-14.

Bridges MW. SOA in healthcare, sharing system resources while enhancing interoperability within and between healthcare organizations with service-oriented architecture. Health Manag Technol 2007 Jun;28(6):6, 8, 10.

Briggs B. An ASP enables a slow approach. Health Data Manag 2001 Feb;9(2):46-8, 50-1.

Brown CA, Bailey JH, Davis MEM, et al. Improving patient safety through information technology. Perspect Health Inf Manag2005;2:5.

Brown RL, Baumann LJ, Cameron L. Single-level analysis of intervention studies with hierarchically structured data: a cautionary note. Nurs Res 1996 Nov-Dec;45(6):359-62.

Brown TNM. An ethnographic study of electronic health record (EHR) use in solo/small group primary care practices in the United States. US: ProQuest Information & Learning; 2008.

Buchsbaum DG, Buchanan RG, Lawton MJ, et al. A program of screening and prompting improves short-term physician counseling of dependent and non-dependent harmful drinkers. Arch Intern Med 1993 Jul;153(13):1573-7.

Buckley S, Bisordi J, Hamory B. Organizational climate. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic heath record system. London: Springer; 2005. p. 3-8.

Buffone GJ, Moreau D. A conceptual framework for managing clinical processes. Comput Nurs 1997;15(2):S53-60.

Bussard BE, McAlearney AS, Pedersen CA, et al. Adoption of technology to improve medication safety: perspectives of pharmacy directors. J Patient Saf 2006 December 2006;2(2):217-24.

Byron J, Zych E, Wolf T, et al. Translating scope of practice into effective EHR workflows. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 77-88.

Cabana MD, Rand CS, Powe NR, et al. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA 1999 Oct;282(15):1458-65.

Callen JL, Westbrrol JI, Braithwaite J. The effect of physicians' long-term use of CPOE on their test management work practices. J Am Med Inform Assoc 2006 Nov-Dec;13(6):643-52.

Camire E, Moyen E, Stelfox HT. Medication errors in critical care: risk factors, prevention and disclosure. Can Med Assoc J 2009 Apr;180(9):936-E29.

Campbell EM, Sittig DF, Ash JS, et al. Types of unintended consequences related to computerized provider order entry. J Am Med Inform Assoc 2006 Sep-Oct;13(5):547-56.

Capital Health Plan. Practice profiles on electronic prescribing—Capital Health Plan. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-CapitalHealth.pdf. Accessed November 13, 2009.

Carayon P, Wetterneck TB, Hundt AS, et al. Evaluation of nurse interaction with bar code medication administration technology in the work environment. J Patient Saf 2007 March 2007;3(1):34-42.

Carneal G, David B. Recent medical management trends. Lippincotts Case Manag 2006 Jan-Feb;11(1):52-7.

Carnegie Mellon University. Computational analysis of social and organizational systems (CASOS)—home. 2009. Available at: http://www.casos.cs.cmu.edu/index.php. Accessed June 19, 2009.

Carson C. 2008 Davies ambulatory care award application. Edmond, OK: Oklahoma Arthritis Center, P.C.; 2008.

Carter J, Samuels C. Workflow. In: Nolan K, editor. Electronic health records: a guide for clinicians and administrators. 2nd ed. East Peoria, IL: Versa Press; 2008. p. 453-72.

Casalino LP. Disease management and the organization of physician practice. JAMA 2005;293(4):485-8.

Celler BG, Lovell NH, Basilakis J. Using information technology to improve the management of chronic disease. Med J Aust 2003 Sep;179(5):242-6.

Centers for Medicare & Medicaid Services. Medicare demonstrations: Medicare care management performance demonstration. 2006. Available at: http://www.cms.hhs.gov/DemoProjectsEvalRpts/MD/itemdetail.asp?itemID=CMS1198950. Accessed April 20, 2009.

Centers for Medicare & Medicaid Services. Medicare program; physicians' referrals to health care entities with which they have financial relationships; exceptions for certain electronic prescribing and electronic health records arrangements; Final Rule. 2006. Available at: http://www.cms.hhs.gov/quarterlyproviderupdates/downloads/cms1303f.pdf. Accessed May 20, 2009.

Centers for Medicare & Medicaid Services. Promising practices in state survey agencies. 2008. Available at: http://www.cms.hhs.gov/SurvCertPromPractProj/Downloads/complaintsfinal.pdf. Accessed May 20, 2009.

Chablani G. Peer perspectives on electronic prescribing: building efficiency, providing checks and balances. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-Chablani_NB.pdf. Accessed November 11, 2009.

Chapel T. Constructing and using logic models in program evaluation. In: Roberts A, Yeager K, editors. Evidence-based practice manual: research and outcome measures in health and human services. New York: Oxford University Press; 2004. p. 636-47.

Chaudhry B. Computerized clinical decision support: Will it transform healthcare? J Gen Intern Med 2008 Jan;23:85-7.

Chen PW. An unforeseen complication of electronic medical records. The New York Times. 2010 April 22.

Cho S, Mathiassen L, Nilsson A. Contextual dynamics during health information systems implementation: an event-based actor-network approach. European Journal of Information Systems 2008 Dec;17(6):614-30.

Christensen T, Grimsmo A. Development of functional requirements for electronic health communication: preliminary results from the ELIN project. Inform Prim Care 2005;13(3):203-8.

Chua R, Craig J, Esmonde T, et al. Telemedicine for new neurological outpatients: putting a randomized controlled trial in the context of everyday practice. J Telemed Telecare 2002;8(5):270-3.

Classen DC, Avery AJ, Bates DW. Evaluation and certification of computerized provider order entry systems. J Am Med Inform Assoc 2007 Jan-Feb;14(1):48-55.

Classen DC. Clinical decision support systems to improve clinical practice and quality of care. JAMA 1998 Oct;280(15):1360-1.

Cohen SJ, Christen AG, Katz BP, et al. Counseling medical and dental patients about cigarette smoking—the impact of nicotine gum and chart reminders. Am J Public Health 1987 Mar;77(3):313-6.

Coiera E, Westbrook JI, Wyatt JC. The safety and quality of decision support systems. Methods Inf Med 2006;45:20-5.

Coiera EW, Westbrook JI. Should clinical software be regulated? Med J Aust 2006 Jun;184(12):600-1.

Coile RC, Jr. A millennium mindset: the long boom. J Healthc Manag 2001 Mar-Apr;46(2):86-90.

Coleman Associates. Patient visit redesign. 2009. Available at: http://www.patientvisitredesign.com/index.html. Accessed July 9, 2009.

Coleman Associates. The no-show reduction playbook: A tool for PCS teams. 2007. Available at: http://www.patientvisitredesign.com/docs/No_Show_Reduction_Playbook_revised_1.29.pdf. Accessed 2009 July 20.

Coleman Associates. The Rapid Redesign Test (RRT) toolkit. 2005. Available at: http://www.patientvisitredesign.com/docs/RRT_ToolKit_PDF.pdf. Accessed July 9, 2009.

Computational Analysis of Social and Organizational Systems. 2009. Available at: http://www.casos.cs.cmu.edu/. Accessed June 17, 2009.

Conn J. Agreement could put EHRs on fast track. Groups' compromise could lead to standard being added to CCHIT criteria by '08. Mod Healthc 2007 Feb 26;37(9):22.

Connecticut Multispecialty Group. Practice profiles on electronic prescribing—Connecticut Multispecialty Group. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Conn Multi-Specialties.pdf. Accessed November 13, 2009.

Contributors. In: Kiel JM, editor. Information technology for the practicing physician. New York: Springer; 2001. p. xvii–xix.

Cook D, Giacomini M. The trials and tribulations of clinical practice guidelines. JAMA 1999 May;281(20):1950-1.

Corrigan J, McNeill D. Building organizational capacity: a cornerstone of health system reform. 2008 May 27-28; Princeton, NJ; 2008. p. W205-W15.

Council M. A framework for development and evaluation of RCTs for complex interventions to improve health. London, Medical Research Council 2000.

Craig JJ, Mcconville JP, Patterson VH, et al. Neurological examination is possible using telemedicine. J Telemed Telecare 1999 July 6, 1999;5(3):177-81.

Crespo R, Shrewsberry M. Factors associated with integrating self-management support into primary care. Diabetes Educator 2007 Jun;33:126S-31S.

Croft P, Porcheret M. Standardised consultations in primary care. Br Med J 2009 Mar;338.

Crosson J, Isaacson N, Lancaster D, et al. Variation in electronic prescribing implementation among twelve ambulatory practices. J Gen Intern Med 2007;23(4):364-71.

Crosson JC, Ohman-Strickland PA, Hahn KA, et al. Electronic medical records and diabetes quality of care: results from a sample of family medicine practices. 2005 May 02; New Orleans, LA; 2005. p. 209-15.

Crow C. 2007 Davies ambulatory care award application. Plano, TX: Family Medical Specialists of Texas; 2007.

Crump W, Tessen R. Communication in integrated practice networks: using interactive video technology to build the medical office without walls. Tex Med 1997;93(3):70.

Culp L, Adams J, Byron J, et al. Phased implementation. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 111-9.

Culp L. Optimizing specialty practices. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 128-33.

Cunningham T, Bartlett K. Integrated telematic support for paediatrics: a practical model. J Telemed Telecare 1996;2 Suppl 1:50-4.

Cupit LG. A systems approach to reducing waiting time in outpatient clinics. Nurs Econ 1985 May-Jun;3(3):140-5, 77.

Currell R, Urquhart C, Wainwright P, et al. Telemedicine versus face to face patient care: effects on professional practice and health care outcomes. Cochrane Database Syst Rev 2000;2.

Curry J, McGregor C, Tracy S. A communication tool to improve the patient journey modeling process. Conf Proc IEEE Eng Med Biol Soc 2006;1:4726-30.

Cuvo J, Dinh A, Fahrenholz C, et al. Quality and documentation for EHRs in physician practice. J AHIMA 2008;79(8):43-8.

Dahl L, Hasvold P, Arild E, et al. Heart murmurs recorded by a sensor based electronic stethoscope and e-mailed for remote assessment. Arch Dis Child 2002;87(4):297.

Daigrepont JP. Achieving the return on investment. In: Landholt T, editor. Automating the medical record. 2nd ed. Chicago, IL: AMA Press; 2004. p. 89-95.

Daigrepont JP. Converting to electronic medical records. In: Landholt T, editor. Automating the medical record. 2nd ed. Chicago, IL: AMA Press; 2004. p. 41-50.

Daigrepont JP. Evaluating electronic medical record features. In: Landholt T, editor. Automating the medical record. 2nd ed. Chicago, IL: AMA Press; 2004. p. 57-73.

D'Aunno T. Managing the care of health and the cure of disease: arguments for the importance of integration. Health Care Manage Rev 2001 Winter;26(1):85-7; discussion 9-90.

de Lusignan S, Wells S, Russell C, et al. Development of an assessment tool to measure the influence of clinical software on the delivery of high quality consultations. A study comparing two computerized medical record systems in a nurse run heart clinic in a general practice setting. Med Inform Internet Med 2002 Dec;27(4):267-80.

de Lusignan S. Developing primary care informatics. Inform Prim Care 2008;16(1):1-2.

Deegan AX, 2nd. Results-oriented ambulatory care management. J Ambul Care Manage 1981 Feb;4(1):1-14.

Demaerschalk BM. The stroke-thrombolytic predictive instrument provides valid quantitative estimates of outcome probabilities and aids clinical decision-making. Stroke 2006 Dec;37(12):2865-6.

Denekamp Y. Clinical decision support systems for addressing information needs of physicians. Israel Medical Association Journal 2007 Nov;9(11):771-6.

Derose SF, Dudl JR, Benson VM, et al. Point-of-service reminders for prescribing cardiovascular medications. Am J Manag Care 2005 May;11(5):298-304.

Dimick C. Anticipating the EHR. A coding department gets ahead of the curve with workflow analysis. J AHIMA 2007 Jul-Aug;78(7):56.

Doebbeling BN, Pekny J. The role of systems factors in implementing health information technology. 2008. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2359513&tool=pmcentrez. Accessed May 20, 2009.

Donabedian A. The evaluation of medical care programs. Bulletin of the New York Academy of Medicine 1968;44(2):117.

Dorr DA, Wilcox AB, Brunker CP, et al. The effect of technology-supported, multidisease care management on the mortality and hospitalization of seniors. J Am Geriatr Soc 2008 Dec;56(12):2195-202.

Dudley N. Allocation of outpatient clinic time in geriatric medicine: a survey of responses to the Royal College of Physicians' guidelines. Age Ageing 2000 Sep;29(5):461.

Duffy JR. Implementing the Quality-Caring Model in acute care. J Nurs Adm 2005 Jan;35(1):4-6.

Dumay A, Freriks G. Quality mangement issues for medical ICT. In: Bos L, Laxminarayan S, Marsh A, editors. Medical care compunetics 1. The Netherlands: IOS Press; 2004. p. 93-100.

Durieux P, Trinquart L, Colombet I, et al. Computerised advice on drug dosage to improve prescribing practice. Cochrane Database Syst Rev 2009;1.

Durieux P, Trinquart L, Colombet I, et al. Computerized advice on drug dosage to improve prescribing practice. Cochrane Database Syst Rev 2008(3).

Dykes PC, McGibbon M, Judge D, et al. Workflow analysis in primary care: implications for EHR adoption. AMIA Annu Symp Proc 2005:944.

E-HIM Work Group on Implementing Electronic Signatures. Implementing electronic signatures (AHIMA practice brief). J AHIMA 2003.

Epstein AM, Lee TH, Hamel MB. Paying physicians for high-quality care. N Engl J Med 2004 Jan;350(4):406-10.

Etherington I. Telecolposcopy—a feasibility study in primary care. J Telemed Telecare 2002;8:22.

Evans RS, Classen DC, Pestotnik SL, et al. Improving empiric antibiotic selection using computer decision support. Arch Intern Med 1994 Apr;154(8):878-84.

Evers RW, Yousem DM, Deluca T, et al. PACS and unread images. Acad Radiol 2002 Nov;9(11):1326-30.

Fahrenholz C, Buck S. PHRs and physician practices. J AHIMA 2007;78(4):71-5.

Fazi P, Grifoni P, Luzi D, et al. Is workflow technology suitable to represent and manage clinical trials? In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 302-6.

Feifer C, Nemeth L, Vietert PJ, et al. Different paths to high-quality care: three archetypes of top-performing practice sites. 2005 Oct 15-18; Quebec City, Canada; 2005. p. 233-41.

Fernando B, Savelyich BSP, Avery AJ, et al. Prescribing safety features of general practice computer systems: evaluation using simulated test cases. Br Med J 2004 May;328(7449):1171-2.

Ferrauiola L, Bordonaro B. One-on-One with HUMC's CIO Lex Ferrauiola & CTO Ben Bordonaro. Hackensack University Medical Center's IT chiefs are taking on the ultimate task—a big to big conversion. Interview by Anthony Guerra. Healthc Inform 2008 Oct;25(10):58-9.

Ferris D, Litaker M, Macafee M, et al. Remote diagnosis of cervical neoplasia: 2 types of telecolposcopy compared with cervicography. J Fam Pract 2003;52(4):298-312.

Figge HL. Electronic prescribing in the ambulatory care setting. Am J Health Syst Pharm 2009 Jan;66(1):16-8.

Finch T, Mort M, May C, et al. Telecare: perspectives on the changing role of patients and citizens. J Telemed Telecare 2005 July 1, 2005;11(suppl_1):51-3.

Finch TL, Mair FS, May CR. Teledermatology in the UK: lessons in service innovation. Br J Dermato 2007 Mar;156(3):521-7.

Fleiss JL, Cohen J. Equivalence of weighted kappa and intraclass correlation coefficient as measures of reliability. Educ Psychol Meas 1973;33(3):613-9.

Flett P, Curry A, Peat A. Reengineering systems in general practice—a case study review. Int J Inf Manage 2008 Apr;28(2):83-93.

Formoso G, Moja L, Nonino F, et al. Clinical evidence: a useful tool for promoting evidence-based practice? BmcHealth Serv Res 2003 Dec;3.

Fortney JC, Pyne JM, Edlund MJ, et al. Design and implementation of the Telemedicine-Enhanced Antidepressant Management study. Gen Hosp Psychiatry 2006 2006 Jan-Feb;28(1):18-26.

Frank R, Gina V. Sustainable solutions for practice profitability. Health Manag Technol 2004;25(1):28.

Freyer FJ. Managing to get by? Behav Healthc Tomorrow 2002 Jun;11(3):14-9, 39-40.

Frieden TR, Mostashari F. Health care as if health mattered. JAMA 2008 Feb;299(8):950-2.

Friedman JH. Electronic medical records. Med Health R I 2008 Sep;91(9):266.

Frist B, Clinton H. How to heal health care. Washington Post. August 2004;25:2004.

Fullerton C, Aponte P, Hopkins R, III, et al. Lessons learned from pilot site implementation of an ambulatory electronic health record. Baylor University Medical Center Proceedings 2006;19(4):303-9.

Gagnon MP, Lepage-Savary D, Gagnon J, et al. Introducing patient perspective in health technology assessment at the local level. BmcHealth Serv Res 2009 Mar;9.

Gagnon MP, Shaw N, Sicotte C, et al. Users' perspectives of barriers and facilitators to implementing EHR in Canada: A study protocol. Implement Sci 2009 Apr;4.

Gamache E. First, a true health care system. Hosp Health Netw 2004 Sep;78(9):10, 2.

Garde S, Knaup P, Herold R. Qumquad: a UML-based approach for remodeling of legacy systems in health care. Int J Med Inform 2003;70(2-3):183-94.

Gardner BH, Demello S. Transformational leadership. Systems thinking in action. Healthc Forum J 1993 Jul-Aug;36(4):25-8.

Gardner S, Frantz R, Specht J, et al. How accurate are chronic wound assessments using interactive video technology? J Gerontol Nurs 2001;27(1):15.

Gardner-Bonneau D, Gosbee J, Ritchie E, et al. Human factors issues in the design and evaluation of an IVR application for mental disorder screening. Human Factors and Ergonomics Society Annual Meeting Proceedings 1996;40:1279.

Garg AX, Tonelli M. The tension between e-health innovation and e-valuation. Arch Intern Med 2005 Nov;165(20):2329-30.

Garibaldi RA. Computers and the quality of care—a clinician's perspective. N Engl J Med 1998 Jan;338(4):259-60.

Geiger G, Derman YD. Methodology for evaluating physician order entry (POE) implementations. J Eval Clin Pract 2003 Nov;9(4):401-8.

George M, Rowlands D, Price M, et al. The Lean Six Sigma pocket toolbook. New York: McGraw–Hill; 2005.

German PS, Shapiro S, Skinner EA, et al. Detection and management of mental-health problems of older patients by primary care providers. JAMA 1987 Jan;257(4):489-93.

Gesteland PH, Nebeker JR, Gardner RM. These are the technologies that try men's souls: common-sense health information technology. Pediatrics 2006 Jan;117(1):216-7.

Gibson H, Kirwan B, Kennedy R, et al. Nuclear action reliability assessment (NARA), further development of a data-based HRA tool. In: Bust P, editor.

Contemporary ergonomics 2008. Great Britain: Taylor & Francis; 2008. p. 164-9.

Gill B, Kammer E, Kram M. Best practice labor management within healthcare. 2007 Society for Health Systems Conference; 2007; New Orleans, LA: 2007.

Gill R, Walker J. Optimizing inpatient care. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 141-52.

Gold JD, Lehmann CU, Lehmann HP, et al. Workflow and problem domain as information planning tools in a pediatric clinic—defining present and future information technology needs. AMIA Annu Symp Proc 2005:964.

Goldstein M, Coleman R, Tu S, et al. Translating research into practice: organizational issues in implementing automated decision support for hypertension in three medical centers. J Am Med Inform Assoc 2004 Sep-Oct;11(5):368-76.

Goldzweig CL, Towfigh A, Maglione M, et al. Costs and benefits of health information technology: new trends from the literature. 2008 May 27-28; Princeton, NJ; 2008. p. W282-W93.

Goodyear-Smith F, Wearn A, Everts H, et al. Pandora's electronic box: GPs reflect upon email communication with their patients. Inform Prim Care 2005;13(3):195-202.

Gorelick D. Peer perspectives on electronic prescribing: Adopt and adapt, then reap the rewards. 2009. Available at: http://www.surescripts.com/peer-perspectives-for-physicians.html. Accessed November 18, 2009.

Goud R, Jaspers MW, Hasman A, et al. Subjective usability of the CARCDS guideline-based decision support system. Stud Health Technol Inform 2008;136:193-8.

Graber ML. Taking steps towards a safer future: Measures to promote timely and accurate medical diagnosis. Am J Med 2008 May;121(5):43-6.

Graham LE, McGimpsey S, Wright S, et al. Could a low-cost audio-visual link be useful in rheumatology? J Telemed Telecare 2000 February 10, 2000;6(suppl_1):35-7.

Grant RW. Next generation of health information tools: Where do we go from here? Mayo Clinic Proceedings 2008 Jul;83(7):745-6.

Greatbatch D, Hanlon G, Goode J, et al. Telephone triage, expert systems and clinical expertise. Sociol Health Illn 2005;27(6):802-30.

Greco PJ, Eisenberg JM. Changing physician practices. N Engl J Med 1993 Oct;329(17):1271-4.

Greiver M. Some positive steps for preventive health. Can Fam Physician 2006 Apr;52:436.

Gross PA, Bates DW. A pragmatic approach to implementing best practices for clinical decision support systems in computerized provider order entry systems. J Am Med Inform Assoc 2007 Jan-Feb;14(1):25-8.

Guidelines for Economic Evaluation of Pharmaceuticals. 1997. Available from: http://www.ccohta.ca/newweb/pubapp/pdf/peg_e.pdf. Accessed 2001 December 15.

Guthrie B, Inkster M, Fahey T. Tackling therapeutic inertia: role of treatment data in quality indicators. Br Med J 2007 Sep;335(7619):542-4.

Guyatt GH, Sackett DL, Cook DJ. Users' guides to the medical literature. 2. How to use an article about therapy or prevention. A. Are the results of the study valid? JAMA 1993 Dec;270(21):2598-601.

Gysels M, Higginson IJ. Interactive technologies and videotapes for patient education in cancer care: systematic review and meta-analysis of randomised trials. Support Care Cancer 2007 Jan;15(1):7-20.

Hailey D, Roine R, Ohinmaa A. Assessments of telemedicine applications—an update. STAKES and Alberta Heritage Foundation for Medical Research (AHFMR); 2001.

Hakkinen H, Korpela M. A participatory assessment of IS integration needs in maternity clinics using activity theory. Int J Med Inform 2007 Nov-Dec;76(11-12):843-9.

Harno KSR. Telemedicine in managing demand for secondary-care services. J Telemed Telecare 1999 July 6, 1999;5(3):189-92.

Harrison MI, Koppel R, Bar-Lev S. Unintended consequences of information technologies in health care—an interactive sociotechnical analysis. J Am Med Inform Assoc 2007 Sep-Oct;14(5):542-9.

Hartley C, Jones E. An electronic medical record system: your electronic workflow assistant in the medical office. EHR Implementation: AMA Press; 2005. p. 37-81.

Hashimoto F, Bell S. Improving outpatient clinic staffing and scheduling with computer simulation. J Gen Intern Med 1996;11(3):182-4.

Haskins M. Legible charts! Experiences in converting to electronic medical records. Can Fam Physician 2002 Apr;48:768-71.

Haynes B, Haynes GA. What does it take to put an ugly fact through the heart of a beautiful hypothesis? Ann Intern Med 2009 Mar;150(6).

Hazelzet JA. Computerized physician order entry: Friend or foe? Pediatr Crit Care Med 2007 May;8(3):304-5.

Health Care TG of HFES. Welcome to the new HCTG website. 2009. Available at: http://hctg.wordpress.com/. Accessed May 20, 2009.

Health information technology. E-prescribing will not greatly disrupt workflow in outpatient practices if carefully implemented. AHRQ Research Activities 2008(336):14.

Heathfield HA, Buchan IE. Current evaluations of information technology in health care are often inadequate. Br Med J 1996 Oct;313(7063):1008.

Helmons PJ, Grouls RJE, Roos AN, et al. The potential value on medication safety of a clinical decision support system in intensive care patients with renal insufficiency. 2006 Sep 27; Netherlands; 2006. p. 504.

Henry E. Optimizing primary-care practices. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 120-7.

Herbert CL, Yoder LM. Creating the ultimate healing environment: integrating evidence-based design, IT and patient safety. Healthc Exec 2008 Sep-Oct;23(5):16-8, 20, 2-3.

Hermens HJ, Vollenbroek-Hutten MMR. Towards remote monitoring and remotely supervised training. J Electromyogr Kinesiol 2008 Dec;18(6):908-19.

Hersh WR, Hickam DH, Severance SM, et al. Diagnosis, access and outcomes: update of a systematic review of telemedicine services. J Telemed Telecare 2006;12:3-31.

Hersh WR. Adding value to the electronic health record through secondary use of data for quality assurance, research, and surveillance. Am J Manag Care 2007 Jun;13(6):277-8.

Hessen S. 2008 Davies ambulatory care award application. Philadelphia: Cardiology Consultants of Philadelphia; 2008.

HIMSS. Davies ambulatory care award recipient manuscript. 2009. Available at: http://www.himss.org/davies/pastRecipients_ambulatory.asp. Accessed May 20, 2009.

HIMSS. EHR Implementation in ambulatory care. Chicago: HIMSS Ambulatory Paperless Clinics Work Group; 2007.

Hing E, Burt CW. Are there patient disparities when electronic health records are adopted? J Health Care Poor Underserved 2009 May;20(2):473-88.

Hoggle LB, Michael MA, Houston SM, et al. Electronic health record: Where does nutrition fit in? J Am Diet Assoc 2006 Oct;106(10):1688-95.

Holbrook A, Xu S, Banting J. What factors determine the success of clinical decision support systems? AMIA Annu Symp Proc; 2003. p. 862.

Horn S, Hudak S, Sharkey S. Case study: process redesign prior to HIT implementation achieves results and increases adoption of HIT in nursing homes. Available at: http://www.ahima.org/meetings/ltc/documents/ICOR.HMS_CaseStudy.pdf. Accessed May 20, 2009.

Horsky J, Zhang JJ, Patel VL. To err is not entirely human: complex technology and user cognition. J Biomed Inform 2005 Aug;38(4):264-6.

Houston M, Myers J, Levens S, et al. Clinical consultations using store-and-forward telemedicine technology. 1999: Mayo Foundation; 1999. p. 764-9.

Huber DL, Blanchfield K. Telephone nursing interventions in ambulatory care. J Nurs Adm 1999 Mar;29(3):38-44.

Huis In 't Veld MH, van Dijk H, Hermens HJ, et al. A systematic review of the methodology of telemedicine evaluation in patients with postural and movement disorders. J Telemed Telecare 2006 September 1, 2006;12(6):289-97.

Hundt AS, Carayon P, Smith PD, et al. A macroergonomic case study assessing electronic medical record implementation in a small clinic. Human Factors and Ergonomics Society Annual Meeting Proceedings 2002;46:1385-8.

Hunkeler E, Meresman J, Hargreaves W, et al. Efficacy of nurse telehealth care and peer support in augmenting treatment of depression in primary care. Arch Fam Med 2000;9(8):700.

Huser V, Narus SP, Rocha RA. Evaluation of a flowchart-based EHR query system: a case study of RetroGuide. J Biomed Inform 2009; In Press, Corrected Proof.

Huser V, Rocha RA, James BC. Use of workflow technology tools to analyze medical data. 19th IEEE Symposium on Computer-Based Medical Systems (CBMS'06), 2006 Jun 22-23; Salt Lake City, UT; 2006. p. 455-60.

Hübner U, Klein F, Hofstetter J, et al. Building a web-based drug ordering system for hospitals: from requirements engineering to prototyping. In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 62-7.

Hägglund M, Scandurra I, Koch S. Using scenarios to capture work processes in shared home care. In: Westbrook J, Coiera E, Callen J, et al., editors. Information technology in health care 2007. Amsterdam: IOS Press; 2007. p. 233-9.

Iakovidis I. From medical informatics to eHealth and biomedical informatics: overview of EU activities and achievements. In: Blobel B, Gell G, Hildebrand C, et al., editors. Contribution of medical informatics to health: integrated clinical data and knowledge to support primary, secondary, tertiary and home care. Berlin: Akademische Verlagsgesellschaft Aka GmbH; 2004. p. 24-30.

Iglehart JK. The National Committee for Quality Assurance. N Engl J Med 1996 Sep;335(13):995-9.

Illyes M, Mengden T, Tisler A. The virtual hypertension clinic. Blood Press Monit 2001 Oct 28-30;7(1):67-8.

Influenza C. Influenza and pneumococcal vaccination coverage among persons aged >65 years and persons aged 18—64 years with diabetes or asthma—United States, 2003. MMWR Morb Mortal Wkly Rep 2004;53:1007-12.

Innes M, Skelton J, Greenfield S. A profile of communication in primary care physician telephone consultations: application of the Roter Interaction Analysis System. Br J Gen Pract 2006 May;56(526):363-8.

Institute for Healthcare Improvement. Home page. 2009. Available at: http://www.ihi.org/ihi. Accessed May 20, 2009.

Institute for Healthcare Improvement. Tools: backlog reduction worksheet. 2009. Available at: http://www.ihi.org/IHI/Topics/OfficePractices/Access/Tools/Backlog+Reduction+Worksheet+IHI+Tool.htm. Accessed July 9, 2009.

Institute for Healthcare Improvement. Unplanned activity card. 2009. Available at: http://www.ihi.org/IHI/Topics/OfficePractices/Access/Tools/UnplannedActivityCardExample.htm. Accessed July 9, 2009.

Jacklin PB, Roberts JA, Wallace P, et al. Virtual outreach: economic evaluation of joint teleconsultations for patients referred by their general practitioner for a specialist opinion. Br Med J 2003 Jul;327(7406):84-8A.

Jackson R, Wells S. Prediction is difficult, particularly abut the future. Arch Intern Med 2007 Nov;167(21):2286-7.

Jacobs B. Hardly child's play: implementing a pediatric-specific, integrated CPOE system. Health Manag Technol 2004;25(8):30-2.

Jacobs BR, Brilli RJ, Hart KW. Perceived increase in mortality after process and policy changes implemented with computerized physician order entry. Pediatrics 2006 Apr;117(4):1451-2.

Jimmerson C, Weber D, Sobek D. Reducing waste and errors: piloting lean principles at Intermountain Healthcare. Jt Comm J Qual Saf 2005;31(5):249-57.

Joffe AM. Information technology and infectious diseases: promise and pitfalls. 2007. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2533570&tool=pmcentrez. Accessed May 20, 2009.

Joffe AM. Information technology and infectious diseases: promise and pitfalls. Can J Infect Dis Med Microbiol 2007 Nov-Dec;18(6):337-9.

Johnson KB, FitzHenry F. Case report: activity diagrams for integrating electronic prescribing tools into clinical workflow. J Am Med Inform Assoc 2006;13(4):391-5.

Johnston B, Weeler L, Deuser J, et al. Outcomes of the Kaiser Permanente tele-home health research project. Arch Fam Med 2000;9(1):40.

Johnston D, Chung M. Achieving excellence using on-line patient chart documentation tracking. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Kaplan B. Evaluating informatics applications–some alternative approaches: theory, social interactionism, and call for methodological pluralism. Int J Med Inform 2001 Nov;64(1):39-55.

Kaplan B, Morelli R, Goethe J. Preliminary findings from an evaluation of the acceptability of an expert system in psychiatry. AMIA Symposium; 1997: American Medical Informatics Association; 1997.

Kassirer JP. A report card on computer-assisted diagnosis—the grade—C. N Engl J Med 1994 Jun;330(25):1824-5.

Kauffold M. Heart specialists incorporate performance improvement measures into EMR. Perform Improv Advis 2005 Jun;9(6):66-7, 1.

Kay S, Redman R, McWilliams A, et al. SAPPHIRE: scenarios, architecture, and process. Comput Methods Programs Biomed 1994 Jun;43(3-4):217-25.

Keen J. The NHS programme for information technology—this massive natural experiment needs evaluating and regulating. Br Med J 2006 Jul;333(7557):3-4.

Kelly J. Inbox. Paperless practice: Texas physician practice eliminates paper from the workflow improving efficiency. Hosp Health Netw 2001;75(11):26.

Kemp AH, Hatch A, Williams LM. Computerized neuropsychological assessments: pros and cons. Cns Spectrums 2009 Mar;14(3):118-9.

Kern LM, Kaushal R. Health information technology and health information exchange in New York State: New initiatives in implementation and evaluation. J Biomed Inform 2007 Dec;40(6):S17-S20.

Khoury A. Support of quality and business goals by an ambulatory automated medical record system in Kaiser Permanente of Ohio. Eff Clin Pract: ECP 1998;1(2):73.

Kidd M. The better Medication Management System: implications for Australian general practice. Aust Fam Physician 2002;31(6):516-20.

Kilbridge P, Classen D, Bates D, et al. The national quality forum safe practice standard for computerized physician order entry: updating a critical patient safety practice. J Patient Saf 2006 December 2006;2(4):183-90.

King R. Peer perspectives on electronic prescribing: guarding against potential medication errors. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-King_NB.pdf. Accessed November 18, 2009.

Kirwan B, Gibson H. Current trends in human reliability assessment. In: Bust P, editor. Contemporary ergonomics 2008. Great Britain: Tayor & Francis; 2008. p. 158-63.

Kleiman J. Practice profiles on electronic prescribing–Dr. Jeffrey Kleiman. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Kleiman.pdf. Accessed November 13, 2009.

Kling R. Social analyses of computing—theoretical perspectives in recent empirical research. Computing Surveys 1980;12(1):61-110.

Koepsell TD, Helfand KH, Diehr PH, et al. The Seattle evaluation of computerized drug profiles: effect on provider activities. Med Care 1983 May;21(5):497-507.

Kohn L, Corrigan J, Donaldson M. To err is human: building a safer health system: National Academy Press; 2000.

Kohout TW, Broekemeier RL, Daniels CE. Work-sampling evaluation of an upgraded outpatient pharmacy computer system. Am J Hosp Pharm 1983 Apr;40(4):606-8.

Kopec D, Shagas G, Reinharth D, et al. Development of a clinical pathways analysis system with adaptive bayesian nets and data mining techniques. In: Bos L, Laxminarayan S, Marsh A, editors. Medical care compunetics 1. The Netherlands: IOS Press; 2004. p. 70-80.

Koppel R, Kreda D. health care information technology vendors' "hold harmless" clause implications for patients and clinicians. JAMA 2009 Mar;301(12):1276-8.

Koppel R. Defending computerized physician order entry from its supporters. Am J Manag Care 2006 Jul;12(7):369-70.

Krall MA. Acceptance and performance by clinicians using an ambulatory electronic medical record in an HMO. Proc Annu Symp Comput Appl Med Care 1995:708-11.

Krauss D. Perioperative patient tracking system implementation: change management and project management that works. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Kros JF, Pang RY. A decision support system for quantitative measurement of operational efficiency in a blood collection facility. Comput Methods Programs Biomed 2004 Apr;74(1):77-89.

Krum W. Training. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 60-6.

Kunst E, Geelkerken R, Rödel S. The EAG tool: a decision support system for selection of abdominal aorta eneurysm endografts. In: Bos L, Laxminarayan S, Marsh A, editors. Medical and care compunetics 1. The Netherlands: IOS Press; 2004. p. 259-61.

Kuperman GJ, Reichley RM, Bailey TC. Using, commercial knowledge bases for clinical decision support: Opportunities, hurdles, and recommendations. J Am Med Inform Assoc 2006 Jul-Aug;13(4):369-71.

Kurtin SE. Clinical tools for success in managing care. Semin Nurse Manag 1995 Jun;3(2):100-6.

Kushniruk AW, Patel VL, Cimino JJ. Usability testing in medical informatics: cognitive approaches to evaluation of information systems and user interfaces. J Am Med Inform Assoc 1997:218-22.

Lahey Clinic. Implementing an order-entry and result-report. Comput Healthc 1989;10(4):27.

Lamothe L, Fortin JP, Labbe F, et al. Impacts of telehomecare on patients, providers, and organizations. Telemed J E Health 2006;12(3):363-9.

Landis SE, Hulkower SD, Pierson S. Enhancing adherence with mammography through patient letters and physician prompts: a pilot study. N C Med J 1992(53):575-8.

Langley J, Beasley C. Health information technology for improving quality of care in primary care settings. 2007. Available at: http://healthit.ahrq.gov/portal/server.pt/gateway/PTARGS_0_1248_661809_0_0_18/AHRQ_HIT_Primary_Care_July07.pdf. Accessed May 20, 2009.

Larson J, Torossian E. Changing behaviors and organizational outcomes through leadership and change management. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Larson J. Using structured dialogue to map organizational change. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Leavitt M. Pilot testing of initial electronic prescribing standards. 2007. Available at: http://www.cms.hhs.gov/EPrescribing/Downloads/E-RxReporttoCongress.pdf. Accessed May 20, 2009.

Lederman S. 2008 Davies ambulatory care award application. Lake Worth, FL: Palm Peach Obstetrics & Gynecology PA; 2008.

Ledlow GR, Bradshaw DM. Animated simulation: a valuable decision support tool for practice improvement. J Healthc Manag 1999 Mar-Apr;44(2):91-101; discussion 2.

Lee H-R, Yoo SK, Jung S-M, et al. A Web-based mobile asthma management system. J Telemed Telecare 2005 July 1, 2005;11(suppl_1):56-9.

Lee J, Cain C, Young S, et al. The adoption gap: health information technology in small physician practices. Health Aff 2005;24(5):1364-6.

Lee M, Delaney C, Moorhead S. Building a personal health record from a nursing perspective. Int J Med Inform 2007 Oct;76 Suppl 2:S308-16.

Lepley CJ. Simulation software: engineer processes before reengineering. J Nurs Adm 2001 Jul-Aug;31(7-8):377-85.

Lesselroth BA, Adams S, Felder R, et al. Using consumer-based kiosk technology to improve and standardize medication reconciliation in a specialty care setting. Jt Comm J Qual Patient Saf2009;35(5):264-70.

Lester WT, Ashburner JM, Grant RW, et al. Mammography fasttrack: an intervention to facilitate reminders for breast cancer screening across a heterogeneous multi-clinic primary care network. J Am Med Inform Assoc 2009;16(2):187-95.

Leu MG, Cheung M, Webster TR, et al. Centers speak up: the clinical context for health information technology in the ambulatory care setting. 2007 Aug 28; Dallas, TX; 2007. p. 372-8.

Levy FH. Technology and pediatric patient safety: What to target is the dilemma. Journal of Pediatrics 2008 Feb;152(2):153-5.

Lewis M. A primer on wireless networks. Fam Pract Manag 2004 Feb;11(2):69-70.

Lieber S. Someday we'll all be on the same page. The long journey toward common health data record-keeping is well under way. Mod Healthc 2004 Feb 23;34(8):24.

Limaye S, Mastrangelo C. A model to reduce the risk of infection transmission in ICUs. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Linder JA, Schnipper JL, Tsurikova R, et al. Barriers to electronic health record use during patient visits. AMIA Annu Symp Poc; 2006; 2006. p. 499-503.

Liu C, Fortney J, Vivell S, et al. Time allocation and caseload capacity in telephone depression care management. Am J Manag Care 2007;13(12):652-60.

Livaudais G, Post J. Thinking beyond the electronic chart—optimizing your practice with panel management. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Lobach D, Hammond W. Development and evaluation of a Computer-Assisted Management Protocol (CAMP): improved compliance with care guidelines for diabetes mellitus. 1994: American Medical Informatics Association; 1994. p. 787.

Longo P. Amplifying performance measurement literacy: reflections from the Appalachian Partnership for Wefare Reform. In: Roberts A, Yeager K, editors. Evidence-based practice manual: research and outcome measures in health and human services. New York: Oxford University Press; 2004. p. 804-12.

Longo P. Application of logic models in rural program development. In: Roberts A, Yeager K, editors. Evidence-based practice manual: research and outcome measures in health and human services. New York: Oxford University Press; 2004. p. 796-804.

Loree A, Maihack M, Powell M. The path of least resistance: is there a better route? Radiol Manage 2003 Sep-Oct;25(5):48-51.

Lorenzi NM, Kouroubali A, Detmer DE, et al. How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. 2009. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2662829&tool=pmcentrez&rendertype=abstract. Accessed May 20, 2009.

Lovell NH, Celler BG. Information technology in primary health care. Int J Med Inform 1999 Jul;55(1):9-22.

Lowe P, Hearnshaw H, Griffiths F. Attitudes of young people with diabetes to an Internet-based virtual clinic. J Telemed Telecare 2005 July 1, 2005;11(suppl_1):59-60.

Lusignan SD, Althans A, Wells S, et al. A pilot study of radiotelemetry for continuous cardiopulmonary monitoring of patients at home. J Telemed Telecare 2000 February 10, 2000;6(suppl_1):119-22.

Luter M. Smart storage. Texas cancer center ensures continuous treatment by using emerging storage networking technology. Health Manag Technol 2003 May;24(5):20-3.

Lyons M. Human reliability assessment in healthcare—where next? In: Bust P, editor. Contemporary ergonomics 2008. Great Britain: Taylor & Francis; 2008. p. 369-74.

Mackey TA, Cole FL, Lindenberg J. Quality improvement and changes in diabetic patient outcomes in an academic nurse practitioner primary care practice. J Am Acad Nurse Pract 2005;17(12):547-53.

Maglione M. Costs and benefits of health information technology. 2006. Available at: http://www.ahrq.gov/downloads/pub/evidence/pdf/hitsyscosts/hitsys.pdf. Accessed May 20, 2009.

Mallett R. Teledermatology in practice. Clin Dermatol 2003;28(4):356-9.

Mangrulkar RS. Targeting and structuring information resource use: a path toward informed clinical decisions. CME Congress 2004. J Contin Educ Health Prof 2004;24:S13-21.

Manos T. Value stream mapping—an introduction. Qual Prog 2006;39(6):64-9.

Marcy TW, Kaplan B, Connolly SW, et al. Developing a decision support system for tobacco use counselling using primary care physicians. Inform Prim Care 2008;16(2):101-9.

Martin K. Metrics-based process mapping: using metrics to design waste-free processes and drive ongoing improvement. 2009. Available at: http://www.iienet2.org/Details.aspx?id=14432. Accessed June 24, 2009.

Masspro. DOQ–IT/HIT Services: DOQ–IT University–Overview. 2009. Available at: http://www.masspro.org/HIT/DOQU/index.php. Accessed May 20, 2009.

Maviglia SM, Zielstorff RD, Paterno M, et al. Automating complex guidelines for chronic disease: lessons learned. J Am Med Inform Assoc 2003;10(2):154-65.

Mayer B. Wary, but prepared. Health Manag Technol 2009;30(3):12.

Mayer M. Peer perspectives on electronic prescribing: trading in the old ways for easier days. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-Mayer_NB.pdf. Accessed November 11, 2009.

McAlearney AS, Schweikhart SB, Medow MA. Organizational and physician perspectives about facilitating handheld computer use in clinical practice: results of a cross-site qualitative study. 2004 Oct; Denver, CO; 2004. p. 568-75.

McAlister NH, Covvey HD, Tong C, et al. Randomized controlled trial of computer-assisted management of hypertension in primary care. Br Med J 1986 Sep;293(6548):670-4.

McBride S. The integrated revenue cycle. Healthc Financ Manage 2004;58(6):38-40.

McCarthy T, Johnson M. How the EHR transforms the HIM department: two stories. J AHIMA 2002;73(8):43-7.

McCoy T. Developing an ED process improvement plan that will work in 13 hospitals. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

McDonald CJ. Protocol-based computer reminders, quality of care and non-perfectability of man. N Engl J Med 1976;295(24):1351-5.

McGowan JJ, Cusack CM, Poon EG. Formative evaluation: a critical component in EHR implementation. J Am Med Inform Assoc 2008 May-Jun;15(3):297-301.

McGowan JJ. The pervasiveness of telemedicine: adoption with or without a research base. J Gen Intern Med 2008 Apr;23(4):505-7.

McGrayne J. Key measures for throughput performance in the emergency department. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

McIntosh WA, Alston LT, Booher JR, et al. Time spent with patients and charges to patients for specialty consultations using telemedicine. Telemed J E Health2003 Winter;9(4):345-50.

McKeough TT, Mentzer JD. What works. Front-end finesse. A combination of the right technology and adept planning and implementation skills brings financial efficiency to a Phoenix specialty practice. Health Manag Technol 2003 Mar;24(3):42-3.

McMullin S, Lonergan T, Rynearson C. Twelve-month drug cost savings related to use of an electronic prescribing system with integrated decision support in primary care. J Manag Care Pharm 2005;11(4):322.

McMullin ST, Lonergan TP, Rynearson GS, et al. Impact of an evidence-based computerized decision support system on primary care prescription costs. Ann Fam Med 2004 Sep-Oct;2(5):494-8.

Medical Group Management Association. Calculating net revenue for an information technology purchase. Englewood, CO; 2005.

Medical Group Management Association. Medical Group Management Assocation. 2009. Available at: http://www.mgma.com/. Accessed May 20, 2009.

Medved C, Flug R. Census & patient flow management system payback. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Mehta NB, Partin MH. Electronic health records: A primer for practicing physicians. Cleveland Clinic Journal of Medicine 2007 Nov;74(11):826-30.

Memel DS, Scott JP, McMillan DR, et al. Development and implementation of an information management and information technology strategy for improving healthcare services: a case study. J Healthc Inf Manag 2001 Fall;15(3):261-85.

Mercurlo G. Practice profiles on electronic prescribing—Dr. Greg Mercurlo. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Mercurio.pdf. Accessed November 13, 2009.

Metastar. Metastar. 2009. Accessed 2009 March 19. Available at: http://www.metastar.com/web/

Metcalf L. Reducing operating room holds—a multidisciplinary approach. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Michigan's Quality Improvement Organization. Tools: return on investment (ROI) worksheet. 2009. Available at: http://www.qualitynet.org/dcs/ContentServer?cid=1163010459793&pagename=Medqic%2FMQTools%2FToolTemplate&c=MQTools. Accessed June 29, 2009.

Miller RA, Gardner RM, Johnson KB, et al. Clinical decision support and electronic prescribing systems: a time for responsible thought and action. J Am Med Inform Assoc 2005 Jul-Aug;12(4):403-9.

Mind Tools Ltd. Mind Tools. 2009. Available at: http://www.mindtools.com/ 180. Accessed August 24, 2009.

Mizzelle G. Diagnostic testing in the physician's office—workflow and data challenges. Health IT Advisory Report 2003;4(7):12-4.

Mohr T. The second time around. Health Manag Technol 2008;29(9):22-5.

Monroe C, Ermer E. Understanding lean principles that dramatically impact process performance. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Montross-Lopez E. Peer perspectives on electronic prescribing: connecting with pharmacies in the neighborhood—and nationwide. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-Montross_NB.pdf. Accessed November 13, 2009.

Moons KGM, Royston P, Vergouwe Y, et al. Prognosis and prognostic research: application and impact of prognostic models in clinical practice. Br Med J 2009 Feb;338.

Morera T, Gervasini G, Carrillo JA, et al. Using a computerized drug prescription screening system to trace drug interactions in an outpatient setting. Ann Pharmacother 2004 Jul-Aug;38(7-8):1301-6.

Mulvaney SA, Bickman L, Giuse NB, et al. A randomized effectiveness trial of a clinical informatics consult service: impact on evidence-based decision-making and knowledge implementation. J Am Med Inform Assoc 2008 Mar-Apr;15(2):203-11.

Munsterman K, Poston S. Linking performance to improvement: using a system wide measurement tool. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Murphy JA, Ahlstrom JS. Nursing process redesign with the implementation of a computer based patient record in the ambulatory setting. Stud Health Technol Inform 1997;46:323-9.

Murphy-Knoll L. Nurses and the Joint Commission tracer methodology. J Nurs Care Qual 2006 Jan-Mar;21(1):5-7.

Murray MD, Harris LE, Overhage JM, et al. Failure of computerized treatment suggestions to improve health outcomes of outpatients with uncomplicated hypertension: results of a randomized controlled trial. Pharmacotherapy 2004 Mar;24(3):324-37.

Murray MD, Loos B, Tu W, et al. Work patterns of ambulatory care pharmacists with access to electronic guideline-based treatment suggestions. Am J Health Syst Pharm 1999 Feb 1;56(3):225-32.

Maass M, Asikainen P, Maenpaa T, et al. Usefulness of a regional health care information system in primary care—a case study. Comput Methods Programs Biomed 2008 Aug;91(2):175-81.

Nancy B. In record time: diary of an EMR installation. Health Manag Technol 2003;24(2):28.

Nassaralla CL, Naessens JM, Chaudhry R, et al. Implementation of a medication reconciliation process in an ambulatory internal medicine clinic. Qual Saf Health Care 2007;16(2):90-4.

Naul LG, Sincleair ST. Radiology goes filmless—what does this mean for primary care physicians? Postgrad Med 2001 Jun;109(6):107.

Nayak NR, Meghea C, Bhargavan M, et al. Prevalence of productivity-enhancing technologies in radiology. Am J Roentgenol 2008 Jun;190(6):1445-52.

Neil N, Group PCPW. Improving rates of screening and prevention by leveraging existing information systems. Jt Comm J Qual Saf 2003 Nov;29(11):610-8.

Nelson TM. From the ground up. Health Manag Technol 2008;29(2):40.

Nelson TR, Kellner AL. High-performance clinical patient data review and consultation system. Stud Health Technol Inform 1997;39:289-97.

Nemeth L, Wessell A, Jenkins R, et al. Strategies to accelerate translation of research into primary care within practices using electronic medical records. J Nurs Care Qual 2007 Oct-Dec;22(4):343-9.

Nemeth LS. Implementing change in primary care practice [dissertation]. Columbia: Medical University of South Carolina; 2005.

Newman D, Smith J, Geehan M, et al. Documenting change in addiction treatment systems: a model for evaluation and examples of its use. In: Roberts A, Yeager K, editors. Evidence-based practice manual: research and outcome measures in health and human services. New York: Oxford University Press; 2004. p. 665-76.

Newman-Toker DE, Pronovost PJ. Diagnostic errors-the next frontier for patient safety. JAMA 2009 Mar;301(10):1060-2.

Nguyen D, Benedict A. Improving inventory management through information systems optimization, process improvement and quality control methodologies. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

NHS Management Executive. Computerisation in GP practices: 1993 Survey. London, Department of Health: 1993.

Niekamp C, Holland M, Rudy J, et al. Getting real results from patient throughput projects. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Nieuwlaat R, Connolly SJ. Stroke prevention in atrial fibrillation: better use of anticoagulation and new agents will lead to improved outcomes. Heart 2009 Feb;95(2):95-7.

Noel HC, Vogel DC, Erdos JJ, et al. Home telehealth reduces healthcare costs. Telemed J E Health 2004 Summer;10(2):170-83.

Nøhr C, Botin L. Methodology for analysis of work practice with video observation. In: Westbrook J, Coiera E, Callen J, et al., editors. Information Technology in Health Care 2007. Amsterdam: IOS Press; 2007. p. 291-7.

Oates R. Information technology and work flow reengineering improves and revitalizes primary care. Healthc Inf Manage 1997 Winter;11(4):113-20.

O'Brien L. Setting the standard. West Coast healthcare network mandates ERP system to ensure business standardization in four states. Health Manag Technol 2003 Sep;24(9):18-21.

Odell S. Next-generation health plans: managing the customer experience. Health Manag Technol 2005 Apr;26(4):48, 7.

Ohinmaa A, Hailey D, Roine R, et al. The assessment of telemedicine: general principles and a systematic review: Finnish Office for Health Care Technology Assessment. Alberta Heritage Foundation for Medical Research; 1999.

Ohinmaa A, Reponen J, Group W. A model for the assessment of telemedicine and a plan for testing the model within five specialities. FinOHTA report no. 5 1997.

Ohmann C, Dedombal FT, Winding O, et al. Evaluation procedure in the telegastro project. Theor Surg 1994 Apr;9(2):90-103.

O'Neill L, Klepack W. Electronic medical records for a rural family practice: a case study in systems development. J Med Syst 2007;31(1):25-33.

Ostini R, Hegney D, Jackson C, et al. Systematic review of interventions to improve prescribing. Ann Pharmacother 2009 Mar;43(3):502-13.

Overhage JM, Perkins S, Tierney WM, et al. Research paper—controlled trial of direct physician order entry: Effects on physicians time utilization in ambulatory primary care internal medicine practices. J Am Med Inform Assoc 2001 Jul-Aug;8(4):361-71.

Pagliari C, Gilmour M, Sullivan F. Electronic clinical communications implementation (ECCI) in Scotland: A mixed-methods programme evaluation. J Eval Clin Pract 2004 Feb;10(1):11-20.

Pandey S. Response to request for information by Seema Pandey of Infosys Technologies Ltd. on August 24, 2009. Center for Quality and Productivity Improvement; 2009. p. 1-4.

Panella L, Tinelli C, Pizzagalli P, et al. Planning the provision of outpatient services in a rehabilitation clinic. G Ital Med Lav Ergon 2002 Jan-Mar;24(1):66-71.

Patel VL, Arocha JF, Diermeier M, et al. Methods of cognitive analysis to support the design and evaluation of biomedical systems: the case of clinical practice guidelines. J Biomed Inform 2001 Feb;34(1):52-66.

Patient-Centered Primary Care Collaborative. Meaningful connections: a resource guide for using health IT to support the patient centered medical home. 2009. Available at: http://www.pcpcc.net/files/cehia_mc.pdf. Accessed June 4, 2009.

Patterson ES, Woods DD, Roth EM, et al. Three key levers for achieving resilience in medication delivery with information technology. J Patient Saf 2006 March 2006;2(1):33-8.

Pauker SG, Zane EM, Salem DN. Creating a safer health care system—finding the constraint. JAMA 2005 Dec;294(22):2906-8.

Payne TH. Computer decision support systems. Chest 2000 Aug;118(2):47S-52S.

Peay J. Clarity from chaos [electronic health record]. Health Manag Technol 2006;27(2):46-7.

Pedersen S, Hartviksen G, Haga D. Teleconsultation of patients with otorhinolaryngologic conditions: a telendoscopic pilot study. Archives of Otolaryngology, Head & Neck Surgery 1994;120(2):133-6.

Perkinson J. Case study: small town success. Available at: https://www.texmed.org/uploadedFiles/Practice_Management/Computers_And_Software/Small Town Success.pdf. Accessed May 20, 2009.

Phillips B, Westwood M. Testing our understanding of tests. Arch Dis Child2009 Mar;94(3):178-9.

Phillips CM, Balch D, Schanz S, et al. Teledermatology: issues in remote diagnosis and management of cutaneous disease. Curr Probl Dermatol 2002 Jan-Feb;14(1):7-38.

Phillips RA, Andrieni JD. Translational patient care—a new model for inpatient care in the 21st century. Arch Intern Med 2007 Oct;167(19):2025-6.

Physicians EHR Inc. Physicians EHR–Home. 2008. Available at: http://www.physiciansehr.org/index.asp. Accessed June 11, 2009.

Pierce M, Lundy S, Palanisamy A, et al. Prospective randomized controlled trial of methods of call and recall for cervical cytology screening. Br Med J 1989 Jul;299(6692):160-2.

Pizziferri L, Kittler A, Volk L, et al. Primary care physician time utilization before and after implementation of an electronic health record: a time-motion study. J Biomed Inform 2005 Jun;38(3):176-88.

Pluto DM, Hirshorn BA. Process mapping as a tool for home health network analysis. Home Health Care Serv Q 2003;22(2):1-16.

Po L, Aquilino K. Peer perspectives on electronic prescribing: decision-support functionality, right at your fingertips. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-Po-Aquilino_NB.pdf. Accessed November 11, 2009.

Poissant L, Tamblyn R, Mayo N. A workflow model for adapting e-charts in specialty clinics. AMIA Annu Symp Proc 2003:973.

Poon EG, Gandhi TK, Sequist TD, et al. "I wish I had seen this test result earlier!": Dissatisfaction with test result management systems in primary care. Arch Intern Med 2004 Nov 8;164(20):2223-8.

Postolache O, Girao PS, Sinha P, et al. Health status monitor based on embedded photoplethysmography and smart phone. 2008 May 09-10; Ottawa, Canada; 2008. p. 39-43.

Poulymenopoulou M, Vassilacopoulos G. An electronic patient record implementation using clinical document architecture. In: Bos L, Laxminarayan S, Marsh A, editors. Medical care compunetics 1. The Netherlands: IOS Press; 2004. p. 50-7.

Priebe III C, Rose E. Workflow automation with electronic medical records. In: Norris T, Fuller S, Goldberg H, et al., editors. Informatics in primary care. New York: Springer; 2002. p. 152-65.

Pugh M. Dashboards and scorecards: tools for creating alignment. In: Ransom E, Joshi M, Nash D, et al., editors. The Healthcare quality book: vision, strategy, and tools. 2nd ed. Chicago: Health Administration; 2008. p. 217-42.

Purcell GP. What makes a good clinical decision support system—we have some answers, but implementing good decision support is still hard. Br Med J 2005 Apr;330(7494):740-1.

Quinn M. Developing a manager scorecard to improve performance. 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Quinn M. Directing a successful process improvement group. 2007 Society for Health Systems Conference; 2007; New Orleans, LA; 2007.

Qureshi SY, Qureshi N. Genetic profiling in primary care can enhance personalized drug therapy: reality or myth? Per Med 2008 Jul;5(4):311-6.

Ragan M. Peer perspectives on electronic prescribing: charting a chartless future. 2009. Available at: http://www.surescripts.com/downloads/Peer Perspectives-Ragan_NB.pdf. Accessed November 13, 2009.

Randeree E. Exploring physician adoption of EMRs: a multi-case analysis. J Med Syst 2007 Dec;31(6):489-96.

Randolph AG, Haynes RB, Wyatt JC, et al. Users' guides to the medical literature XVIII. How to use an article evaluating the clinical impact of a computer-based clinical decision support system. JAMA 1999 Jul;282(1):67-74.

Reams C. Study reveals risks of unsecured PHI in e-mail communications. In: AHIMA HIM Products, editor. The Best of In Confidence: Selected Readings. Chicago, IL: American Health Information Management Association; 2003. p. 203-5.

Reichert T. Selling your improvement ideas to healthcare. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Reponen J, Marttila E, Paajanen H, et al. Extending a multimedia medical record to a regional service with electronic referral and discharge letters. J Telemed Telecare 2004;10:S1:81-3.

Resnik R. Practice profiles on electronic prescribing—Dr. Robert Resnik. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Resnik.pdf. Accessed November 13, 2009.

Revere L, Black K. Integrating six sigma with total quality management: a case example for measuring medication errors. Healthc Financ Manage 2003;48(6):377-91.

Richards D, Meakins J, Tawfik J, et al. Nurse telephone triage for same day appointments in general practice: multiple interrupted time series trial of effect on workload and costs. 2002. p. 1214.

Richards F. Infrastructure. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 21-35.

Richards F. Managing the client-vendor partnership. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 101-7.

Richards F. Vendor selection and contract negotiation. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 15-20.

Rinkus SM, Chitwood A. Cognitive analyses of a paper medical record and electronic medical record on the documentation of two nursing tasks: patient education and adherence assessment of insulin administration. Proc AMIA Symp 2002:657-61.

Rivkin S. Opportunities and challenges of electronic physician prescribing technology. Med Interface 1997;10(8):77.

Rogers M, Small D, Buchan D, et al. Home monitoring service improves mean arterial pressure in patients with essential hypertension: a randomized, controlled trial. Ann Intern Med 2001;134(11):1024-32.

Rogoski RR. Opening the floodgates of usability. Clinical information systems allow free flow of patient data to clinicians when and where they need it. Health Manag Technol 2003 Sep;24(9):12-7.

Rokita K, Topper J, Lampman M, et al. Extending EHR access to patients. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 153-64.

Roland MO, Zander LI, Evans M, et al. Evaluation of a computer assisted repeat prescribing programme in a general practice. Br Med J (Clinical Research Ed.) 1985 Aug 17;291(6493):456-8.

Roller S. Managing projects and change within organizations. 17th Annual Society for Health Systems Management Engineering Forum; 2005; Dallas, TX; 2005.

Ross MN, Conrad DA, Jha A, et al. Panel discussion: health information technology and return on investment: fact or fantasy? Health Serv Res 2007 Dec;42(6):2294-307.

Ross S, Papshev D, Murphy E, et al. Effects of electronic prescribing on formulary compliance and generic drug utilization in the ambulatory care setting: a retrospective analysis of administrative claims data. J Manag Care Pharm 2005;11(5):410.

Rosser WW, Hutchison BG, McDowell I, et al. Use of reminders to increase compliance with tetanus booster vaccination. Can Med Assoc J 1992 Mar;146(6):911-7.

Rubenstein LV, McCoy JM, Cope DW, et al. Improving patient quality-of-life with feedback to physicians about functional status. J Gen Intern Med 1995 Nov;10(11):607-14.

Ryffdeleche A, Engler H, Nutzi E, et al. clinical application of 2 computerized diabetes management systems—comparison with the log-book method. Diabetes Research Clinical and Experimental 1992 Mar;19(3):97-105.

Scalvini S, Zanelli E, Conti C, et al. Assessment of prehospital chest pain using telecardiology. J Telemed Telecare 2002 August 1, 2002;8(4):231-6.

Schade CP, Sullivan FM, Lusignan S, et al. e-Prescribing, efficiency, quality: lessons from the computerization of UK family practice. J Am Med Inform Assoc 2006 Sep-Oct;13(5):470-5.

Schadel D, Coumbos A, Ey S, et al. Evaluation of a digital store-and-forward colposcopic system—a pilot study to assess usability for telemedicine. J Telemed Telecare 2005;11(2):103-7.

Schock P, Carlson K. Practice profiles on electronic prescribing—Dr. Peter Schock and Dr. Karen Carlson. 2009. Accessed November 13, 2009.Available at: http://www.surescripts.com/downloads/Practice Profiles-Schock-Carlson.pdf

Sensmeier J. United front: nurses and pharmacists. Nurs Manage 2008 Nov;Suppl:2-5.

Sequist TD, Cook DA, Haas JS, et al. Moving health information technology forward. J Gen Intern Med 2008 Apr;23(4):355-7.

Shachak A, Hadas-Dayagi M, Ziv A, et al. Primary care physicians' use of an electronic medical record system: A cognitive task analysis. J Gen Intern Med 2009 Mar;24(3):341-8.

Shah NR, Seger AC, Seger DL, et al. Improving acceptance of computerized prescribing alerts in ambulatory care. J Am Med Inform Assoc 2006 2006 Jan-Feb;13(1):5-11.

Shea S, DuMouchel W, Bahamonde L. A meta-analysis of 16 randomized controlled trials to evaluate computer-based clinical reminder systems for preventive care in the ambulatory setting. J Am Med Inform Assoc 1996 Nov-Dec;3(6):399-409.

Shiffman RN. Towards effective implementation of a pediatric asthma guideline—integration of decision-support and clinical workflow support. 1994 Nov 05-09; Washington, Dc; 1994. p. 797-801.

Shojania KG, Ranji SR, Shaw LK, et al. Closing the Quality Gap: A Critical Analysis of Quality Improvement Strategies, Vol. 2: Diabetes Mellitus Care. Technical Review 9. Rockville, MD: Agency for Healthcare Research and Quality; 2004.

Sicotte C, Denis JL, Lehoux P. The computer based patient record: A strategic issue in process innovation. J Med Syst 1998 Dec;22(6):431-43.

Sicotte C, Lehoux P. Teleconsultation: Rejected and emerging uses. Methods Inf Med 2001;42(4):451-7.

Sicotte C, Lehoux P. Teleconsultation: Rejected and emerging uses. 2001 Sep 06-07; Rotterdam, Netherlands; 2001. p. 451-7.

Silver D. Doing away with paper: part 1—advice for setting up fully computerised medical records. Aust Fam Physician 2002;31(6):521.

Simpson J, Doze S, Urness D, et al. An assessment of routine telepsychiatry services: Alberta Heritage Foundation for Medical Research: Alberta Mental Health Board; 1999.

Singh R, Singh A, Fox C, et al. Computer visualisation of patient safety in primary care: a systems approach adapted from management science and engineering. Inform Prim Care 2005;13(2):135-44.

Sintchenko V, Coiera E, Gilbert GL. Decision support systems for antibiotic prescribing. Curr Opin Infect Dis 2008 Dec;21(6):573-9.

Siriwardena AN. The exceptional potential for quality improvement methods in the design and modelling of complex interventions. Qual Prim Care 2008;16(6):387-9.

Sittig DF, Kuperman GJ, Fiskio J. Evaluating physician satisfaction regarding user interactions with an electronic medical record system. Proc AMIA Symp 1999:400-4.

Smithline N, Christenson E. Physicians and the Internet: understanding where we are and where we are going. J Ambul Care Manage 2001;24(4):39-53.

Sobek D, Jimmerson C. Applying the Toyota production system to a hospital pharmacy. Industrial Engineering Research Conference: 2003.

Sobel E, Krasner D. Peer perspectives on electronic prescribing: trading the prescription pad for a PDA. 2009. Available at: http://www.surescripts.com/downloads/Peer_Perspective_Krasner.pdf. Accessed November 11, 2009.

Society for Health Systems. Society for Health Systems home page. 2009. Available at: http://www.iienet2.org/SHS/Community/Default.aspx. Accessed May 20, 2009.

Sogaard B. Applying advanced excel techniques in a healthcare setting. 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Sport DMoHWa. Health Care in an ageing society: a challenge for all European countries. 1994.. Available at: http://www.minvws.nl/en/folders/iz/health-care-in-an-ageing-society-a-challenge-for-all-european-countries.asp. Accessed April 2, 2007.

Spreckelsen C, Lethen C, Heeskens I, et al. The roles of an intelligent mobile decision support system in the clinical workflow. 2000; Duesseldorf, Germany: VDI/VDE-GMA; 2000. p. 91-4.

St. Mary's Outpatient Surgery Center. RFI pilot test: St. Mary's Outpatient Surgery Center. Madison, WI: St. Mary's Outpatient Surgery Center; 2009.

Staccini P, Joubert M, Quaranta J, et al. Mapping care processes within a hospital: a web-based proposal merging enterprise modelling and ISO normative principles. In: Baud R, Fieschi M, Le Beux P, et al., editors. The new navigators: from professionals to patients–proceedings of MIE2003. The Netherlands: IOS Press; 2003. p. 200-5.

Staccini P, Joubert M, Quaranta J, et al. Modeling health care processes for eliciting user requirements: a way to link a quality paradigm and clinical information system design. In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 51-6.

Staccini PJ, Quaranta JF, Fieschi D, et al. Modelling health care processes for eliciting user requirements: a way to link a quality paradigm and clinical information system design. Stud Health Technol Inform 2000;77:51-6.

Staggers N, Thompson CR, Happ B. An operational model for patient-centered informatics. Comput Nurs 1999 Nov-Dec;17(6):278-85.

Stanton N, Salmon P, Walker G, et al. Human factors methods: a practical guide for engineering and design. Great Britain: Ashgate; 2005.

Sternberg DJ. Make life a little easier. Marketing Health Services 2003 Summer2003;23(2):44-6.

Stock R, Scott J, Gurtel S. Using an electronic prescribing system to ensure accurate medication lists in a large multidisciplinary medical group. Jt Comm J Qual Patient Saf 2009;35(5):271-7.

Stone JH. Communication between physicians and patients in the era of e-medicine. N Engl J Med 2007 Jun;356(24):2451-4.

Tachakra S, Lynch M, Newson R, et al. A comparison of telemedicine with face-to-face consultations for trauma management. J Telemed Telecare 2000 February 10, 2000;6(suppl_1):178-81.

Tague N. The quality toolbox. 2nd ed. Milwaukee, WI: ASQ Quality Press; 2005.

Tamblyn R, Huang A, Kawasumi Y, et al. The development and evaluation of an integrated electronic prescribing and drug management system for primary care. J Am Med Inform Assoc 2006 Mar-Apr;13(2):148-59.

Tang PC, Jaworski MA, Fellencer CA, et al. Methods for assessing information needs of clinicians in ambulatory care. Philadelphia, PA: Hanley &amp, Belfus; 1995. p. 630-4.

Tanriverdi H, Iacono C. Knowledge barriers to diffusion of telemedicine. 1998: Association for Information Systems Atlanta, GA, USA; 1998. p. 39-50.

Taveras M, Omachonu V. Understanding our current state of access to care. 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Taylor CE. The uses of health systems research. Public Health Pap 1984;78:1-50.

Taylor P. An assessment of the potential effect of a teledermatology system. J Telemed Telecare 2000 February 10, 2000;6(suppl_1):74-6.

Te S, Classen J. The price (and coding) is right! 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Tegan A. The EHR's impact on HIM functions. J AHIMA 2005;76(5):56C-H.

Terry K. EMRs cost too much? This group says no way! Med Econ 2002;79(7):34-9.

The American Health Quality Association. Bridges to Excellence: QIO participation toolkit. Available at: http://www.bridgestoexcellence.org/Documents/QIO Participation Toolkit Final 12-27-07.pdf. Accessed May 20, 2009.

The Colorado Health Foundation. The Colorado Health Foundation. 2009. Available at: http://www.bridgestoexcellence.org/Content/Content/26/Documents/CCHIT News Release.pdf. Accessed May 20, 200.

Thomson D, Sparboe-Derry S. Lean from scratch: a first hand perspective. 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Thornett A. Computer use must not affect doctor-patient relationship. Br Med J 2001 Jun;322(7298):1369.

Tierney WM, Overhage JM, McDonald CJ. A plea for controlled trials in medical informatics. J Am Med Inform Assoc 1994 Jul-Aug;1(4):353-5.

Tiffany MN. From the ground up. Health Manag Technol 2008;29(2):40.

Tobey ME. Paperless medical records: reinventing the patient experience. Radiol Manage 2004 May-Jun;26(3):32-5.

Tolomeo C, Shiffman R, Bazzy-Asaad A. Electronic medical records in a sub-specialty practice: one asthma center's experience. Journal of Asthma 2008;45(9):849-51.

Topper J, Dean K. Extending EHR access to external physicians. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 165-9.

Toth-Pal E, Wardh I, Strender LE, et al. Implementing a clinical decision-support system in practice: a qualitative analysis of influencing attitudes and characteristics among general practitioners. Inform Health Soc Care 2008;33(1):39-54.

Trachtenbarg DE. EHRs fix everything—and nine other myths. Fam Pract Manag 2007;14(6):13-.

Trisolini M, Pope G, Kautter J, et al. Medicare physician group practices: innovations in quality and efficiency. 2006. Available at: http://www.cms.hhs.gov/DemoProjectsEvalRpts/downloads/PGP_Conference_Report.pdf. Accessed May 20, 2009.

Trivedi M, Kern J, Marcee A, et al. Development and implementation of computerized clinical guidelines: barriers and solutions. Methods Inf Med 2002;41(5):435.

Tu SW. Guideline models, process specification, and workflow. 2008; Heidelberg, D-69121, Germany: Springer Verlag; 2008. p. 322.

U.S. Department of Health & Human Services. Health IT Tools. The Office of the National Coordinator for Health Information Technology (ONC). 2009. Available at: http://healthit.hhs.gov/portal/server.pt?open=512&objID=1140&parentname=CommunityPage&parentid=51&mode=2&in_hi_userid=10741&cached=true. Accessed May 20, 2009.

U.S. Preventive Services Task Force, Guide to clinical preventive services. 2nd ed. Washington, DC: Office of Disease Prevention and Health Promotion; 2008.

Unertl KM, Weinger MB, Johnson KB. Applying direct observation to model workflow and assess adoption. AMIA Annu Symp Proc 2006:794-8.

University Research Co. LLC. Quality assurance project. 2008. Available at: http://www.qaproject.org/. Accessed July 28, 2009.

Urquhart C, Currell R, Grant MJ, et al. Nursing record systems: effects on nursing practice and healthcare outcomes. Cochrane Database Syst Rev 2009;1.

Van de Ven A, Delbecq A. The effectiveness of nominal, Delphi, and interacting group decision making processes. Acad Manage J 1974:605-21.

Van Hala S. Maximizing workflow with an EHR. Dr. David E. Trachtenbarg's article "EHRs fix everything — and nine other myths" [March 2007]. Fam Pract Manag 2007;14(6):13.

van Rosse F, Maat B, Rademaker CMA, et al. The effect of computerized physician order entry on medication prescription errors and clinical outcome in pediatric and intensive care: a systematic review. Pediatrics 2009 Apr;123(4):1184-90.

Vedsted P, Nielsen JN, Olesen F. Does a computerized price comparison module reduce prescribing costs in general practice? Fam Pract 1997 Jun;14(3):199-203.

Victoroff MS. Breaking the seal for sake of safety. Manag Care 2003 Nov;12(11):14, 6.

W.K. Kellogg Foundation. Logic model development guide. 2004. Available at: http://www.wkkf.org/Pubs/Tools/Evaluation/Pub3669.pdf. Accessed 2009 July 21.

Wadland WC, Holtrop JS, Weismantel D, et al. Practice-based referrals to a tobacco cessation quit line: assessing the impact of comparative feedback vs general reminders. Ann Fam Med 2007;5(2):135-42.

Waegemann CP. Closer to reality. Personal health records represent a step in the right direction for interoperability of healthcare IT systems and accessibility of patient data. Health Manag Technol 2005 May;26(5):16, 8.

Waggoner DM. Application of continuous quality improvement techniques to the treatment of patients with hypertension. Health Care Manage Rev 1992 Summer;17(3):33-42.

Walker J. Summary and prospects. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 173-5.

Walker J, Bieber E, Richards F, et al. Appendix 1. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 179-82.

Walker J, Bieber E, Richards F, et al. Appendix 4. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 197.

Walker J, Bieber E, Richards F, et al. Appendix 6: Low back pain. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 200.

Walker J, Bieber E, Richards F, et al. Appendix 7. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 201-7.

Walker J, Bieber E, Richards F, et al. Appendix 8: EHR user security policy/process. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 208-13.

Walker J, Bieber E, Richards F, et al. Appendix 9. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 214231.

Walker J, Bieber E, Richards F, et al. Appendix 10: Abstraction form. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 222-3.

Walker J, Bieber E, Richards F, et al. Appendix 12. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 226-7.

Walker J, Bieber E, Richards F, et al. Appendix 13: Reference call outline Geisinger information services. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 228-31.

Walker J, Komar M. Special-purpose software. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 134-40.

Walker J, Tingley S. Clinical decision support. In: Walker J, Bieber E, Richards F, editors. Implementing an electronic health record system. London: Springer; 2005. p. 67-75.

Walker JM, Carayon P, Leveson N, et al. EHR safety: the way forward to safe and effective systems. J Am Med Inform Assoc 2008 May-Jun;15(3):272-7.

Walker JM, Carayon P. From tasks to processes: the case for changing health information technology to improve health care. Health Aff 2009 Mar-Apr;28(2):467-77.

Ward R. Information technology applications for improved quality. In: Ransom E, Joshi M, Nash D, et al., editors. The healthcare quality book: vision, strategy, and tools. 2nd ed. Chicago: Health Administration Press; 2008. p. 269-310.

Warner Jr H, Miller S, Jennings K, et al. Clinical event management using push technology—implementation and evaluation at two health care centers. American Medical Informatics Association: 1998. p. 106.

Warrington A. Practice profiles on electronic prescribing—Dr. Alan Warrington. 2009. Available at: http://www.surescripts.com/downloads/Practice Profiles-Warrington.pdf. Accessed November 13, 2009.

Washington L. Analyzing workflow for a health IT implementation: an often short-shrifted step is essential in successful IT deployments. J AHIMA 2008;79(1):64-5.

Washington L. Understanding use cases. J AHIMA 2008;79(2):60-1.

Waton K. Streamlining pediatric patient care. Health Manag Technol 2005 Sep;26(9):36, 9.

Weber V, Bulger J. Implementing healthcare quality improvement: changing clinician behavior. In: Ransom E, Joshi M, Nash D, et al., editors. The healthcare quality book: vision, strategy, and tools. 2nd ed. Chicago: Health Administration Press; 2008. p. 377-403.

Weed J. If all doctors had more time to listen. The New York Times. 2009 June 7, 2009.

Wells BJ, Lobel KD, Dickerson LM. Using the electronic medical record to enhance the use of combination drugs. Am J Med Qual 2003 Jul-Aug;18(4):147-9.

Wentzer H. Technology development and implementation in the public health institutions: a strategic and pedagogical task for the learning organization. In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 264-9.

Wertheimer DE. Physician practice management. What works. A one-two punch. Health Manag Technol 2005 Jun;26(6):14, 6.

Wessman B. Specialty access in outpatient clinics. 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Weyer SM, Konrad N, Esola D, et al. Features of medical records in community practices and their association with preventive service delivery. Med Care 2005 Jan;43(1):28-33.

Whited JD. Teledermatology research review. Int J Dermatol 2006 Mar;45(3):220-9.

Whittlesey J. Breaking the supply chain barrier: can I do this on my own? 2007 Society for Health Systems Conference; New Orleans, LA; 2007.

Wilson R, Bojke C, O'Neill S, et al. Designing, specifying and evaluating a new repeat prescribing process for UK general practice. In: Hasman A, Blobel B, Dudeck J, et al., editors. Medical Infobahn for Europe: Proceedings of MIE2000 and GMDS2000. The Netherlands: IOS Press; 2000. p. 219-23.

Wisconsin Medical Society. Wisconsin Medical Society: Quality and Efficiency. 2009. Available at: http://www.wisconsinmedicalsociety.org/quality_and_efficiency. Accessed May 20, 2009.

Woodcock E. The patient encounter. In: Gaulke R, editor. Mastering patient flow: using lean thinking to improve your practice operations. 3rd ed. Englewood, CO: Medical Group Management Association; 2007. p. 311-59.

Wootton R, Bloomer S, Corbett R, et al. Multicentre randomised control trial comparing real time teledermatology with conventional outpatient dermatological care: societal cost-benefit analysis. Br Med J; 2000. p. 1252-6.

Wu SJ, Lehto M, Yih Y, et al. Relationship of estimated resolution time and computerized clinical reminder adherence. AMIA Annu Symp Proc 2007:334-8.

Yaggie E. Release of information: the basics. J AHIMA 2001;72(5):56-61.

Yawn BP. Telemedicine: a new framework for evaluation. Telemed J 2000 Spr;6(1):55-61.

Young AS, Chaney E, Shoai R, et al. Information technology to support improved care for chronic illness. 2006 Sep 13-15; Arlington, VA; 2006. p. 425-30.

Yu F, Houston TK, Bay MN, et al. Patterns of use of handheld clinical decision support tools in the clinical setting. 2004 Oct 17-20; Atlanta, GA; 2004. p. 744-53.

Zai AH, Grant RW, Estey G, et al. Lessons from implementing a combined workflow-informaties system for diabetes management. 2007 Nov 10-14; Chicago, IL; 2007. p. 524-33.

Zerbe TR. Engineering methods in an ambulatory surgery clinic: a case study in computerized patient tracking. J Ambul Care Manage 1989 Nov;12(4):48-60.

Zheng K. Design, implementation, user acceptance, and evaluation of a clinical decision support system for evidence-based medicine practice. US: ProQuest Information & Learning; 2007.

Zidel T. 5S. In: O'Mara P, editor. A lean guide to transforming healthcare. Milwaukee, WI: ASQ Quality Press; 2006. p. 73-86.

Zidel T. Mistake proofing. In: O'Mara P, editor. A lean guide to transforming healthcare. Milwaukee, WI: ASQ Quality Press; 2006. p. 87-97.

Zidel T. Standard work. In: O'Mara P, editor. A lean guide to transforming healthcare. Milwaukee, WI: ASQ Quality Press; 2006. p. 45-71.

Appendix F: Tool Compendium

The Tool Compendium is a table of all the workflow analysis tools and methods that will be incorporated into the final Workflow Toolkit.

It is available at: http://healthit.ahrq.gov/workflowtoolcompendium