Health Information Technology: An Updated Systematic Review with a Focus on Meaningful Use Functionalities

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Structured Abstract

Objectives

The purpose of the project described in this report was to update previous systematic reviews focusing on the effects of health information technology (health IT) on key aspects of care, including health care quality, safety, and efficiency. This report provides our current understanding of the effects of health IT across a number of dimensions of care. Unlike reviews conducted prior to the introduction of the federal Meaningful Use Incentive Programs, this review focused specifically on identifying and summarizing the evidence relating to the use of health IT as outlined in the Meaningful Use regulations.

Data Sources

We performed a systematic search of the English-language literature indexed in MEDLINE from January 2010 to August 2013. We also searched the Cochrane Central Register of Controlled Trials, the Cochrane Database of Abstracts of Reviews of Effects, and the Periodical Abstracts Database; and hand-searched personal libraries kept by content experts and project staff. We also asked content experts to identify evidence outside the peer-reviewed literature. Finally, a technical expert panel identified additional published articles and non-peer reviewed resources.

Review Methods

The systematic review was carried out in three stages by two health IT subject matter experts, with input from a panel of five nationally-known health IT experts. The reviewers used a webbased system to conduct the screening process. The first stage involved independent, dual-rater screening of articles based on their titles against a set of defined on the inclusion/exclusion criteria. The next stage involved screening each article at the abstract level using a standardized abstraction form. The final stage of the screening process involved a full text review and classification using a standardized abstraction form. Inclusion/exclusion or classification discrepancies between the two reviewers were resolved by consensus. We conducted multiple update searches using the same search terms through October 2013 using a computer-aided screening system that extends a previously described approach for facilitating systematic review updating.

Results

The systematic review identified 12,678 titles, and through the screening process, we identified 236 studies meeting the eligibility criteria: assessing the effect of health IT on healthcare quality,

safety, and efficiency in ambulatory and non-ambulatory care settings. Approximately 77 percent of studies reported positive or mixed-positive findings. The effects of health IT are thought to be sensitive to the particulars of the IT system itself, the implementation process, and the context in which it is implemented, and therefore generalizations across systems and contexts must be made cautiously. Nevertheless, analyses found that neither study setting (ambulatory vs. nonambulatory), nor recognition as a health IT leader, nor commercial status were significantly associated with outcome results. However, studies of efficiency were significantly less likely to report positive results than studies of safety or quality, and studies that evaluated e-prescribing and multifaceted health IT interventions were significantly less likely to report positive results than studies of more targeted clinical decision support or computerized physician order entry interventions. Studies of multifaceted health IT interventions and studies of efficiency have structural challenges that make conclusive results more difficult to obtain than more studies of more narrowly targeted health IT interventions assessing quality or safety outcomes

Conclusions

Overall, a majority of studies that evaluated the effects of health IT on healthcare quality, safety, and efficiency reported findings that were at least partially positive. These studies evaluated several forms of health IT: metrics of satisfaction, care process, and cost and health outcomes across many different care settings. Our findings agree with previous health IT literature reviews suggesting that health IT, particularly those functionalities included in the Meaningful Use regulation, can improve healthcare quality and safety. The relationship between health IT and efficiency is complex and remains poorly documented or understood, particularly in terms of healthcare costs, which are highly dependent upon the care delivery and financial context in which the technology is implemented.

We identified two broad themes in this review. First, the published literature on health IT is expanding rapidly, driven primarily by studies of commercial health IT systems. Second, much of the health IT literature still suffers from methodological and reporting problems that limit our ability to draw firm conclusions about why the intervention and/or its implementation succeeded or failed to meet expectations, and their generalizability to other contexts. Studies of health IT must be designed, conducted, and reported in ways that allow stakeholders to understand study results and how they can replicate or improve on those results.

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Chapter 1. Background and Introduction

The purpose of this project was to update previous systematic reviews that focused on the effects of health information technology (health IT) on key aspects of care. The RAND Corporation, through the Southern California Evidence-based Practice Center (SCEPC) conducted two earlier, high-impact systematic reviews of the health IT literature.^{1, 2}

This report provides our current understanding of the effects of health IT across a number of dimensions of care. Unlike previous reviews conducted prior to the introduction of the federal Meaningful Use Incentive Programs, * this review focused specifically on identifying and summarizing the evidence on the use of health IT as outlined in the Meaningful Use regulations. By targeting the specific functionalities prescribed by Meaningful Use, this report should be helpful to federal policymakers as they seek to communicate the value proposition of the Meaningful Use Programs to healthcare providers and other stakeholders. The Meaningful Use criteria are useful for defining the scope of this literature review because these criteria were developed with the intention of improving care, given the current state of health IT functionality.

1.1 Context and Summary of Previous Systematic Reviews

Need for Updates to Previous Systematic Reviews

A comparison of previous systematic reviews of the health IT literature suggests that the size, composition, and content of the health IT literature are evolving rapidly. Given the rapid evolution of this literature, it is important to review the evidence frequently and systematically in order to assess the direction and impact of the federal government's investment in this area. The purpose of this review was to update previous systematic reviews that focused on the effects of Meaningful Use of health IT on key aspects of care such as quality, patient safety, and efficiency of care. The review described herein updates previous systematic reviews and expands on them by specifically targeting the application of health IT as it is described in the "Meaningful Use" regulations.³

^{*} Meaningful Use is a term used by the CMS to refer to the committed use of health IT (EHRs, in particular) to improve patient care. CMS provides financial incentives for the "Meaningful Use" of certified EHR technology. The criteria for Meaningful Use are delineated in a series of 3 stages associated with specific objectives. The Stage 1 criteria (started in 2011) focus on incentivizing healthcare providers to use health IT to capture and share health information, the Stage 2 criteria (starting in 2014) focus on incentivizing healthcare providers to use health IT to advance clinical processes, and the Stage 3 criteria (starting in 2016) focus on incentivizing healthcare providers to use health IT to improve patient outcomes.

Summary of Previous Systematic Reviews

In 2005, researchers from the SCEPC analyzed 257 studies published during the period 1995 to 2004. Key findings from this systematic review, authored by Chaudhry and colleagues, included the following:

- 25 percent of studies were conducted by just four institutions that were early implementers of health IT. These institutions along with two others were regarded as "health IT Leaders" in this and in subsequent systematic reviews (See Table 3.2.2)
- Only 3.5 percent of studies evaluated commercially developed systems;
- Many of the beneficial effects of health IT had been identified in only a few institutions where the health IT system had been developed and was then evaluated by the same set of clinical champion/researchers. Whether other institutions could expect to achieve these same benefits using commercial systems remained an unanswered question;
- Primary benefits observed in the literature included increased adherence to clinical guidelines, enhanced surveillance and monitoring, decreased medication errors, and decreased utilization;
- Mixed results were obtained for efficiency outcomes, and almost no empirical studies reported cost outcomes

Overall, the systematic review revealed that the health IT literature was limited in its generalizability but that a small set of leading institutions was able to demonstrate improved clinical quality through health IT. A secondary conclusion was that the evidence for efficiency and cost benefits of health IT was not well established.¹

In 2008, a research team from the SCEPC sought to update the previous systematic review by analyzing 179 studies published between 2004 and 2007. Key findings from this review by Goldzweig and colleagues included the following:

- 20 percent of studies were still being conducted by "health IT Leaders;"
- Most studies (91.6 percent) still evaluated only home-grown (not commercially developed) systems;
- Organizations not regarded as "health IT" leaders reported benefits comparable to those reported by the "health IT Leaders";
- Studies that evaluated "stand-alone" health IT applications, patient-centered applications (e.g., personal health records [PHRs]), and facilitators and barriers to successful health IT implementation increased in number;
- The report found that there was still little empirical evidence for the cost effectiveness of health IT.

Overall, this systematic review found that the composition of the health IT literature had shifted since the previous review, that evaluations of commercial systems, standalone technologies, and patient focused systems had increased in number, and that implementation issues were receiving more attention. New studies indicated that some organizations (e.g., Kaiser Permanente) were able to leverage commercial health IT systems to achieve significant gains in areas such as

quality and utilization; however, efficiency and cost-benefit analysis were still the subject of relatively little research.²

Finally, the most recent literature review was conducted by staff of the Office of the National Coordinator for Health Information (ONC) and included 154 studies published between April 2007 and February 2010. Key findings from this systematic review by Buntin and colleagues included the following:

- 18 percent of studies came from "health IT Leaders";
- 64 percent of studies came from single-site implementations or tightly integrated networks;
- The 154 studies evaluated a total of 270 individual outcome measures; health IT had had at least mixed-positive effects on 86 percent of outcome measures; and 92 percent of studies reported overall positive findings;
- Studies conducted in organizations that were not considered "health IT leaders" reported benefits comparable to those of "health IT Leaders;"
- The volume of literature that evaluated electronic health records (EHR), computerized physician order entry (CPOE), and clinical decision support (CDS) (i.e., core elements of "Meaningful Use") had grown since the previous reviews;
- Studies with negative findings were less likely to address Meaningful Use criteria than studies that had positive or neutral findings;
- Dissatisfaction with EHR remains a barrier to adoption and use among some providers;
- The "human element," i.e., leadership and "buy-in," were identified as critical components of success.

Overall, this systematic review revealed that the large majority of health IT studies yield positive results; however, dissatisfaction with EHR and other "sociotechnical" barriers preclude some healthcare providers from realizing the potential benefits of health IT.⁴

1.2 Topic Refinement

Systematic reviews are guided by "key questions," which ultimately determine how the research findings are organized. The first systematic review was guided by three "key questions":

1. What does the evidence show with respect to the costs and benefits of health information exchange for providers and payers/purchasers?

2. What knowledge or evidence deficits exist regarding needed information to support estimates of cost, benefit, and net value with regard to health IT systems?

3. What are the barriers that health care providers and health care systems encounter that limit implementation of electronic health information systems?

With each subsequent review, the key questions were modified to reflect the changing needs of clinicians and policymakers and the relevant issues at the time. For example, the concept of "Meaningful Use" of health IT did not exist in 2005 but is now a topic of great interest to ONC and other stakeholders.

We recruited a technical expert panel (TEP) to help us determine the key questions that should guide this updated systematic review. The TEP included the following members:

- David Bates MD, MSc Senior VP for Quality and Safety, Chief Quality Officer Brigham & Women's Hospital
- Paul Tang, M.D., M.S., is Vice President, Chief Innovation and Technology Officer at the Palo Alto Medical Foundation
- Louise L. Liang, MD, Retired Senior Vice President, Quality and Clinical Systems Support, Kaiser Permanente
- George Hripcsak, MD, Professor and Chair Department of Biomedical Informatics, Columbia University
- Philip J. Aponte, MD, vice president of informatics for the Health Texas Provider Network

As a first step toward formulating our key questions, we used a web-based questionnaire to enlist the TEP in helping us prioritize a list of topics that we hypothesized would be of greatest interest and would be best represented in the current literature (see Appendix). We divided the topic areas into two broad categories: health IT functionalities and health IT associated outcomes. We also asked the TEP to suggest additional topics for the review. After compiling the responses to the web-based questionnaire, we held a teleconference meeting to discuss the TEP's responses and elicit further advice. Examples of the questions and summaries of the TEP responses follow.

i. "The following topics are related to the functionality of health IT. Please rank the following health IT functionality topic areas in order of importance"

- Meaningful Use
- Certified EHR technology
- Health information exchange
- Electronic prescribing
- EHR Usability

The TEP ranked "Meaningful Use" as the most important topic, by a considerable margin, followed by EHR usability and heath information exchange. Suggestions from the TEP included focusing the review on the broad functionalities specified in the Meaningful Use criteria (e.g., electronic prescribing with CPOE). A similar approach was used in the review by Buntin and colleagues when they evaluated the subset of articles that focused on the health IT functionalities included in the Meaningful Use regulations.⁴

ii. "The following topics are related to patient or process outcomes that may be associated with the use of health IT. Please rank the following topic areas in order of importance."

- Medication safety
- Patient safety (separate form medication safety)
- Care coordination
- Chronic disease management
- Efficiency of healthcare delivery
- Heart disease and stroke outcomes (including intermediate outcomes: aspirin therapy, smoking cessation, cholesterol/blood pressure control patient safety)

On average, the TEP ranked chronic disease management, care coordination, and efficiency as the most important topics. However, in general, the TEP members expressed the belief that focus on specific diseases or conditions (e.g., heart disease and stroke outcomes) was unlikely to produce a sufficient number of articles to facilitate meaningful synthesis and analysis, and that focusing on highly specific topics would not be consistent with the previous broadly focused systematic reviews conducted by Chaudhry, Goldzweig, and Buntin.

Based on the feedback from our TEP, and in consultation with project officers from ONC, the research team formulated a three-part "key question" that guided this updated systematic review:

What does the new research evidence show regarding the relationship between the health IT functionalities prescribed in the Meaningful Use regulations and the following key aspects of care:

- 1. **Quality:** including healthcare process quality, health outcomes, and patient and provider satisfaction
- 2. Safety: including medication safety and other manifestations of patient safety
- 3. Efficiency: including healthcare costs, healthcare utilization, and the timeliness and time burden of care

The key question(s) determined the inclusion and exclusion criteria for the review and helped us determine the most intuitive and effective ways to organize our findings. Sections 3.2 through 3.4 of this report provide narrative summaries of the recent literature that describes the relationship between "Meaningful Use" of health IT and the aforementioned key aspects of care.

Chapter 2. Methods

2.1 Search Strategy and Terms

The review included articles published between January 2010 and November 2012. Our initial searches covered the period between January 2010 and November 2011. We started with a systematic search of the English-language literature indexed in MEDLINE using a broad set of terms to maximize sensitivity. The search strategy for this review was based on the strategies used in the Chaudhry, Goldzweig, and Buntin reviews but was adapted to account for our focus

on the functionalities prescribed in the Meaningful Use regulation (see the full list of search terms and sequence of queries below). We also searched the Cochrane Central Register of Controlled Trials, the Cochrane Database of Abstracts of Reviews of Effects, and the Periodical Abstracts Database; and hand-searched the personal libraries of content experts and project staff. In particular, we asked content experts to identify evidence outside the peer-reviewed literature. Finally, we asked our technical expert panel to identify published articles and non-peer reviewed resources up to December 2012. The full list of search terms is available in the Appendix.

We conducted an update search using the same search terms through November 2012 using a computer-aided screening system that extends a previously described approach for facilitating systematic review updating. In a prior application of an earlier version of this system, the computer-aided search system achieved a sensitivity of 0.90-1.0 %. In brief, this system uses citations that were manually selected for inclusion in a systematic review to statistically classify citations later retrieved for updating the same review.⁵ The remainder of this section describes the process in more detail.

First, the system converted previously read citations into a set of explanatory features based on each citation's Medical Subject Heading (MeSH) indexing terms and words in the text of the abstract and title. MeSH processing was used to construct a limited set of important features using key MeSH indexing terms and associated subheadings that are mentioned in the search strategy. In addition, other explanatory features related to broader characteristics from the MeSH indexing terms and publication type fields—including demographic group (gender and age), treatment target (human, animal, in vitro study, and others), and publication type (review, clinical trial, meta-analysis, and others)—were created. To prepare the text features, text was minimally pre-processed and converted to a bag-of-words representation, where terms utilized a Term Frequency – Inverse Document Frequency (TF-IDF) weighting scheme.

Second, the classifier utilized both sets of features, and used a pairwise sampling scheme to estimate a support vector machine that maximizes the number of relevant articles predicted to score higher than an irrelevant article. This created a validated model that uses all explanatory features to predict the manual coding decisions. Finally, the system uses this model to classify unread citations as relevant (or not) based on their text and MeSH features (processed as above into explanatory features). Screeners then manually reviewed these predictions to validate the results. Of note, articles classified in this stage were then passed back to the first stage in several iterations to validate the modeling process and increase the number of training observations.

Finally, we conducted a surveillance search for the period 10/1/2012-8/13/2013. We used the same search terms as the previous searches, however limited our searches to five "core journals" (Annals of Internal Medicine, BMJ, JAMA, Lancet, New England Journal of Medicine) and eight other "key" journals (American Journal of Managed Care, Applied Clinical Informatics, Archives of Internal Medicine (Now Titled JAMA Internal Medicine), Health Affairs, Health Services Research, International Journal of Medical Informatics, Journal of General Internal Medicine, Journal of the American Informatics Association). Based on our earlier work we determined that the majority of relevant articles identified were published in these journals.

2.2 Study Selection and Classification

The systematic review was carried out in three steps by two health IT subject matter experts (Drs. Jones and Rudin). The reviewers used a web-based system, DistillerSR, to conduct the three-stage screening process.

Step 1: Title Screening

The first step was to screen articles based on their titles and on the inclusion/exclusion criteria (describe in Section 2.3, below). Initially, the two reviewers, along with an expert in systematic reviews (Dr. Shekelle), used a sample of 100 titles as a training set to ensure a relatively high level of agreement between reviewers. The two expert reviewers then independently screened all article titles returned from the search. Inclusion/exclusion discrepancies were resolved by consensus.

Step 2: Abstract Screening

The next step of the review involved screening each article at the abstract level using a standardized abstraction form. The reviewers classified articles by study focus (e.g., "Meaningful Use" of health IT, telemedicine, attitudes/barriers/facilitators toward health IT); study design (e.g., randomized controlled trial (RCT), non-RCT hypothesis test; descriptive study, systematic review, pilot study); and study setting (Non-US, health IT leader, etc...).

Step 3: Full Text Screening

The final step of the screening process involved a full text review of all articles that made it through the previous two steps. Again, articles were abstracted independently by both expert reviewers using a standardized abstraction form. The reviewers classified articles according to the type of study design, the clinical setting of the research, which Meaningful Use functionality the study evaluated, whether or not the research was conducted at an organization regarded as a "health IT leader," the type of outcomes reported, the type of healthcare conditions assessed, and whether the research involved commercial or "homegrown" health IT. Articles determined to be out of the scope of the review (e.g., systematic reviews) were excluded. Section 3.1 presents the full systematic review flow diagram.

2.3 Inclusion/Exclusion Criteria

Step 1: Title Screening

Articles with titles that gave some indication that the article evaluated some form of health IT and its effect on one of the key aspects of care (quality, safety, or efficiency) advanced to the next stage of screening. This initial screening tended to be permissive rather than restrictive, e.g. we accepted articles with vague titles like "*Information technology in the service of diabetes prevention and treatment*" for further review, whereas we dropped articles with titles that were obviously not relevant to Meaningful Use of health IT, e.g., "*How Scientists Use Social Media to Communicate Their Research*" from the review.

Step 2: Abstract Screening

As noted above, we performed the abstract screening using a standardized abstraction form (see Appendix). To be included for further review, the abstract had to provide some indication that the article evaluated a health IT functionality encompassed by the Meaningful Use regulations (e.g., CPOE, CDS, problem lists, etc.). We limited our review to hypothesis-testing studies and descriptive quantitative studies; descriptive qualitative studies were excluded. In addition, we excluded the following types of articles at this stage of the review:

- Articles that focused on health IT-related policy or on the rate of health IT adoption (e.g., articles that provided data from surveys about the number and percentage of providers that have implemented health IT).
- Articles in which health IT was not a critical part of the study
- Articles that did not evaluate any of the key aspects of care
- Articles that described early stage health IT prototypes or pilot tests
- Articles that focused on consumer targeted health IT applications that are not integrated with provider facing health IT systems (e.g., a standalone online food and exercise journal would be excluded, but a PHR linked to a provider EHR would be included)
- Articles that offered commentary or non-systematic reviews of the health IT literature
- Articles that described attitudes and barriers/facilitators to health IT adoption
- Articles that described health IT applications beyond the scope of Meaningful Use (e.g., a hospital syndromic surveillance system; or IT to support clinical trials) or that evaluated IT implementations not relevant to Meaningful Use (e.g., implementation of health IT in an Iranian neonatal unit; use of personal health records in sub-Saharan Africa).
- Articles that described telemedicine interventions

Each abstract was classified into one of the following categories based on the study design: prepost study, randomized controlled trial, cohort study, time series study, cross sectional study, pre-post study with concurrent control, descriptive quantitative, or descriptive qualitative. Following the convention of the original review by Chaudhry, we excluded descriptive qualitative articles from the review.

Step 3: Full Text Screening

During the full text review, we used a structured abstraction form to evaluate whether or not articles were relevant to specific Meaningful Use criteria. Table 2.3.1 presents a full list of the Meaningful Use functionalities that determined the inclusion/exclusion decisions at this stage of the review. The Chaudhry and Goldzweig reviews both incorporated prior systematic reviews; however, Buntin and colleagues excluded systematic reviews, reasoning that such reviews would contain articles already included in their review or in the reviews conducted by Chaudhry and Goldzweig. Our literature search identified 23 systematic reviews published since the cut-off date for the Buntin review. Our analysis of these reviews revealed that the original studies they included overlapped considerably with the three previous systematic reviews and the articles that were retrieved by our searches. Therefore, we chose to exclude these articles from the main body of our review.

Meaningful Use "Core" Functionalities				
Record patient demographics				
Record and chart changes in vital signs				
Maintain active medication allergy list				
Maintain an up-to-date problem list of current and active diagnoses				
Maintain active medication list				
Use computerized physician order entry (CPOE) for medication orders				
Generate and transmit electronic prescriptions for non-controlled substances				
Implement drug-drug/drug-allergy interaction checks				
Record adult smoking status				
Provide clinical summaries for patients for each office visit				
On request, provide patients with an electronic copy of their health information				
Implement capability to electronically exchange clinical information among care providers and patient authorized entities				
Implement one clinical decision support rule				
Implement systems to protect privacy and security of patient data in EHR				
Report clinical quality measures to CMS/State				
Meaningful Use "Menu" Functionalities				
Implement drug formulary checks				
Incorporate clinical lab test results in EHR				
Generate patient lists by specific conditions				
Use EHR technology to identify patient-specific education resources				
Perform medication reconciliation between care settings				
Provide summary of care for patients referred or transitioned to another provider or setting				
Submit electronic immunization data to immunization registries or immunization information systems				
Submit electronic syndromic surveillance data to public health agencies				
Send reminders to patients for preventive and follow-up care				
Provide patients with timely electronic access to their health information				

Table 2.3.1: Meaningful Use Functionalities

The final rules for Stage 2 of the Meaningful Use program were released in September 2012, too late for us to incorporate the updated functionalities into this systematic review. We do not believe that this limitation poses a substantial threat to the validity or relevance of our findings. Although the basic functionalities prescribed in Stages 1 and 2 are largely the same, some new functionalities were added in Stage 2. These functionalities include electronic medication administration (eMAR), electronic documentation, electronic (standards-based) images, family history as structured data, electronic prescription of discharge medication orders, exchange of electronic lab results between hospitals and ambulatory providers, and cancer and other specialty disease registry reporting. Although not explicitly coded as such, papers that focused on these new functionalities (with the exception of the structured family history data and submission to cancer and other disease registries) are likely to be included in our review, because these functionalities are most often used in conjunction with other included IT functionalities. For example, we included several articles that evaluated eMAR because it was used in conjunction with CPOE, and we included numerous articles that focused on electronic documentation, because they also focused on CDS.

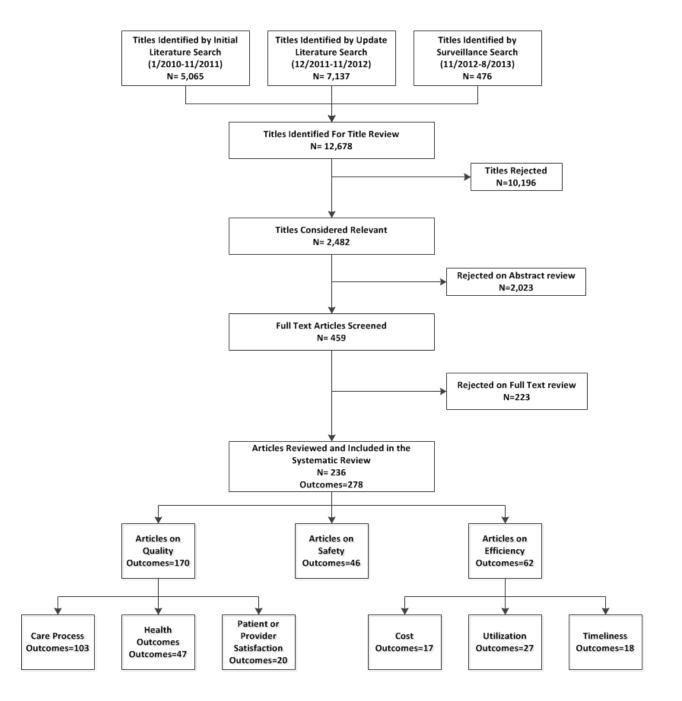
2.4 Data Synthesis

We performed a number of statistical analyses to determine whether the likelihood of reporting positive results varied significantly across different settings, Meaningful Use functionalities, outcome types, or commercial vs. homegrown health IT systems. However, given the broad scope of this review, our ability to quantitatively synthesize the data abstracted from the set of included studies was limited because of the studies included were very diverse in terms of the technologies evaluated, the evaluation context, and the specific outcomes reported. Therefore, the review primarily provides a narrative synthesis of the recent health IT literature. The narrative synthesis is organized around study setting and key aspects of care; Section 3.2 further describes our approach for classifying article characteristics and outcomes.

Chapter 3. Results

3.1 Search Results

Figure 1. Systematic Review Flow



3.2 Description of the Evidence

3.2.1 Summary of Article Characteristics

Table 3.2.1 presents the distribution of articles by study design. Pre-Post designs were most common, followed by randomized controlled trials (RCT) and then time series studies; proportionally, RCTs were somewhat less common (25%) in the most recent literature than they were in the literature review conducted by Chaudhry (37%), but comparable to the review conducted by Goldzweig (25%) (Buntin did not classify articles by study design).^{1, 2}

Study Design	Number of Articles (%)
Pre-Post Study	72 (30.5)
Randomized Controlled Trial	59 (25.0)
Time Series Study	26 (11.0)
Cross Sectional Study	31 (13.1)
Cohort Study	18 (7.6)
Pre-Post Study With Concurrent Control	16 (6.8)
Descriptive Quantitative	14 (5.9)
Total	236

Consistent with the pattern observed in previous reviews, our review found that approximately one in five studies came from institutions regarded as health IT leaders, as defined in previous literature reviews.² (See Table 3.2.2).

Table 3.2.2 Article Count by Study Organizational Setting

Organizational Setting	Number of Articles (%)		
Non-health IT Leaders	187 (79.2)		
Health IT-Leaders	49 (20.8)		
Total	236		

More than half (~53%) the articles evaluated commercial health IT products (See Table 3.2.4); more than a quarter of the articles did not report whether the products they were evaluating were commercial health IT products, a mix of commercial and "homegrown" health IT products, or entirely "homegrown" systems. Typically, articles that we coded as "not specified" were secondary analyses of nationally representative survey data (e.g., the HIMSS, AHA, and NAMCS surveys). Regardless, the proportion of articles reporting evaluations of commercial health IT in this review is substantially higher among the literature identified for this review than that of the reviews by Chaudhry (~4%) and Goldzweig (~8%) (the review by Buntin did not classify articles by commercial status).

Health IT-type	Number of Articles (%)
Commercial health IT	125 (53)
Homegrown health IT	50 (21.2)
Not Specified	61 (25.8)
Total	236

Table 3.2.3 Article Count by health IT-type (Commercial/Homegrown)

Based on input from our TEP, we classified articles based on the type of outcomes they studied into three broad categories: Quality, Safety, and Efficiency. We then attempted to further classify each of these categories into sub-categories. Articles that evaluated the relationship between health IT and healthcare quality were classified as evaluating quality in terms of processes, health outcomes, and satisfaction (both patient and provider); articles that evaluated the relationship between health IT and healthcare safety were divided further into those evaluating medication safety and those evaluating other aspects of patient safety (however, all patient safety articles we identified were related to medication safety). Finally, articles that evaluated the relationship between health IT and efficiency were further classified as evaluating efficiency outcomes measured in time, cost, or utilization.

The distribution of articles across these categories is presented in Table 3.2.4. Some articles evaluated multiple "types of outcomes," e.g., several articles evaluated the relationship between health IT and process quality and health outcomes. Therefore, the sum total of article-outcomes (278) is greater than the sum presented in previous tables (236). More than three times as many articles evaluated the relationship between health IT and quality as articles that evaluated the relationship between health IT and safety or efficiency; and articles that described the effects of health IT on the quality of care processes (e.g., physician adherence to best practices) were more than twice as common as articles that describe the effects of health IT on health outcomes (e.g., patient mortality).

Table 3.2.5 presents the distribution of articles across the different health IT functionalities included in the Meaningful Use regulations. As the table indicates, and consistent with previous systematic reviews, the majority of articles pertained to CDS (\sim 36%) and CPOE (\sim 20%). We did not identify any articles directly pertaining to many of the functionalities prescribed in the Meaningful Use regulations. However, while many of these functionalities were not evaluated in isolation, basic features, such as the capacity to track vital signs or maintain medication allergy lists were undoubtedly critical to the functionalities for which this review identified no articles that met the inclusion criteria include the following:

- Record patient demographics
- Record and chart changes in vital signs
- Maintain active medication allergy list
- Record adult smoking status
- Implement systems to protect privacy and security of patient data in EHR
- Report clinical quality measures to CMS/State

- Implement drug formulary checks
- Perform medication reconciliation between care settings

Table 3.2.4 Article-Outcome Count by Type of Outcome

Outcome Type	Number of Article-Outcomes (%)	
Quality	170 (61.2)	
Process	103 (37.1)	
Health Outcomes	47 (16.9)	
Satisfaction	20 (7.2)	
Safety	46 (16.5)	
Medication	46 (16.5)	
Other	0 (0)	
Efficiency	62 (22.3)	
Time	18 (6.5)	
Cost	17 (6.1)	
Utilization	27 (9.7)	
Total	278	

Table 3.2.5 Article-Outcome Count by Meaningful Use Functionality

Meaningful Use Functionality	Number of Article-Outcomes (%)		
Clinical Decision Support	99 (35.6)		
Computerized Provider Order Entry	56 (20.1)		
Multifaceted health IT Intervention	57 (20.5)		
Electronic Prescribing	15 (5.4)		
Other MU	51 (18.3)		
Total	278		

3.2.2 Classifying Article Outcome Results

As a broad measure of outcome, we adopted and adapted the outcome result classification framework (Positive, Mixed-Positive, Neutral, Negative) originally employed by Buntin and colleagues.⁴ Our adaptations, described below, generally made the classification framework more conservative, thus increasing the likelihood that an article's findings would be classified as mixed, neutral, or negative. In the following paragraphs, we describe the original framework proposed by Buntin as well as our adaptations.

Like Buntin, we acknowledge the shortcomings of categorizing diverse and nuanced findings using a positive-mixed-neutral-negative classification framework. We resort to this framework only to provide a general aggregation for the overall findings reported in the literature. In later sections of this report, we will provide more in-depth narrative summaries of the health IT literature.

Positive

Buntin classified articles as positive when health IT was associated with improvement in key aspects of care, with no aspects worse off. However, we adapted this criterion slightly, so that articles that reported a mix of positive and neutral findings were classified as mixed-positive.

Mixed-Positive

Buntin classified articles as mixed-positive when the article reported at least one negative association between health IT and a key aspect of care but the positive effects of health IT outweighed the negative effects. We expanded this classification as noted above by also classifying articles that contained both positive and neutral (but no negative) findings as mixed-positive. Therefore some articles that Buntin would have classified as positive, we would consider to be mixed-positive. We chose this classification algorithm to account for selective outcome reporting bias. Classifying studies that reported a mixture of positive and neutral outcomes differently from studies that reported all positive outcomes will somewhat counteract the selective outcome reporting bias. As with Buntin's classification scheme, in order to be rated as mixed-positive, the original authors of the article had to conclude that the positive effects of health IT outweighed the neutral or negative effects.

Neutral

We did not change the criteria for a neutral classification from the criteria originally proposed by Buntin, who classified articles as neutral if health IT was not associated with any demonstrable change in any key aspect of care.

Negative

Our classification framework was also consistent with Buntin in classifying negative articles. Buntin classified articles as negative if the article reported only negative findings or presented both negative and positive findings, but the overall conclusion was negative.

3.2.3 Cross-Tabulations of Article Characteristics and Study Results

Many articles reported multiple outcomes (e.g. HITs effect on multiple hospital process quality measures), and some articles reported multiple types of outcomes (e.g., quality, safety, efficiency). For each outcome type reported in an article, we rated the findings as positive, mixed-positive, neutral, or negative. Therefore, studies that evaluated health IT's effects on multiple types of outcomes, e.g., medication safety and process quality, could be classified as positive for process quality but mixed, neutral, or negative for medication safety. For the remainder of section 3.2, the unit of analysis will be the article-outcome, defined as a single outcome type (quality, safety, and efficiency) reported in a given article. The 236 articles in this review reported 278 different article-outcomes.

We used the broad classifications of article outcome results to evaluate whether the results showed any patterns across the different outcome types, study settings (ambulatory vs. non-ambulatory), health IT leader vs. non-leader, Meaningful Use functionality, and commercial status of the health IT. For example, we assessed whether the type of outcome assessed (i.e.,

quality, safety, or efficiency) was associated with the likelihood of reporting positive outcomes. Table 3.2.6 shows the distribution of studies by outcome type and result. Outcome types and Meaningful Use functionalities were significantly associated with the kinds of results reported: Studies of efficiency outcomes were significantly less likely to report positive results than were studies of safety or quality outcomes. In addition, studies that evaluated the effects of eprescribing and multifaceted health IT interventions were also significantly less likely to report positive results (see Table 3.2.7). This finding is likely related to the first, as e-prescribing studies often evaluated efficiency outcomes and evaluations of multifaceted health IT interventions were often cross-sectional studies that evaluated multiple outcomes, thus increasing the likelihood of mixed results. Neither study setting, recognition as a health IT leader, nor commercial status was significantly associated with outcome results.

		Article-Outcome Results (%)			
Outcome Type	Number of Article Outcomes	Positive	Mixed-Positive	Neutral	Negative
Quality	170	57.6%	24.1%	13.5%	4.7%
Efficiency	62	45.2%	19.4%	16.1%	19.4%
Safety	46	67.4%	10.9%	4.3%	17.4%
Total	278	56.5%	20.9%	12.6%	10.1%

		Article-Outcome Results (%)			
Outcome Type	Number of Article Outcomes	Positive	Mixed-Positive	Neutral	Negative
Clinical Decision Support	99	65.7%	13.1%	14.1%	7.1%
Computerized Provider Order Entry	56	64.3%	7.1%	14.3%	14.3%
Electronic Prescribing	15	46.7%	20.0%	6.7%	26.7%
Multifaceted health IT Intervention	57	29.8%	42.1%	15.8%	12.3%
Other Meaningful Use	51	62.7%	27.5%	5.9%	3.9%
Total	278	56.5%	20.9%	12.6%	10.1%

 Table 3.2.7 Cross-tabulation, Article-outcomes by Meaningful Use Functionality and Outcome Result

The remainder of this chapter provides narrative summaries of the results, organized by outcome type (Section 3.3: Quality of care; Section 3.4: Safety; and Section 3.5: Efficiency). Within each outcome type, the results are organized by care settings.

3.3. Narrative Summary: Health IT and Quality of Care

3.3.1 Ambulatory Care Settings

We identified 101 studies that assessed the effect of health IT on quality of care in ambulatory care settings. Twelve studies assessed patient or provider satisfaction, seventy-two studies assessed processes of care, and 17 studies assessed health outcomes. Evidence Table 1 (See Appendix) presents details for each of the included studies.

3.3.1.1 Satisfaction (Patient and Provider)

Twelve studies included in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on patient or provider satisfaction in ambulatory care settings. Ten of the studies reported positive or mixed positive results and two reported neutral effects on satisfaction.

Seven studies evaluated provider satisfaction with health IT. Five of the studies focused on satisfaction with CDS. In the first study, an RCT of CDS for glucose control and blood pressure among diabetes patients, the authors reported very high rates of user satisfaction (94 percent).⁶ In another RCT, 82 percent of physicians given access to passive CDS alerts and documentation templates reported that the CDS system improved the effectiveness of their counseling. However, many physicians believed that the increased time required to use the system was a major barrier.⁷ In a cohort study, 85 percent of clinicians planned to continue to use an EHR-based CDS tool for management of depression in primary care after conclusion of the study.⁸ Finally, a study of 39 family medicine practices reported that 66 percent of the physicians had positive perceptions of the system during the first year of implementation.⁹

Two studies reported on provider satisfaction with non-CDS health IT applications. First, in a pre-post study of EHR satisfaction among 306 ambulatory care providers who recently changed

from one EHR system to another, a small majority of providers were satisfied with both their old (56%) and new (64%) EHRs and 58% of the providers were satisfied with the transition process. However, when asked about specific functionalities, providers were neutral or less satisfied with many specific functionalities of the newer EHRs.¹⁰ A single study of e-prescribing in a single academic ambulatory clinic reported very high patient and provider satisfaction.¹¹

Five studies evaluated patient satisfaction with health IT. A study of tailored patient education via a touch-screen tablet in eleven primary care practices showed significant increases in patients' knowledge of self-medication practices for hypertension as well as improved behavior regarding such practices.¹² In an RCT conducted in eight ambulatory practices, 83 percent of patients reported that they found a wellness patient portal valuable.¹³ However, another RCT reported that PHR use was not associated with significant changes in patient satisfaction and only 25 percent of PHR users frequently accessed their PHR.¹⁴ Finally, one RCT evaluated patient satisfaction with health information exchange, patients rated communication about laboratory tests more highly after the implementation of the exchange (91 vs. 83 on a 100-point scale), but ratings were not higher for other aspects of care.¹⁵

3.3.1.2 Process Outcomes

Seventy-two studies included in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on process quality in ambulatory care settings. The majority of studies focused on CDS alerts and reminders designed to improve adherence to clinical guidelines and preventive care screening; however, fourteen studies focused on multifaceted the effects of health IT interventions on process quality. Fifty-seven of the studies reported positive or mixed-positive results, eleven reported neutral results, and four reported negative results.

Alerts and Reminders: Guideline Adherence

Representative studies of the effects of guideline adherence focused IT interventions include thirty-one studies evaluated CDS alerts and reminders designed to improve adherence to care practice guidelines and completeness of documentation in ambulatory settings. Thirteen of the studies reported that CDS was associated with significant improvements in adherence to clinical guidelines. Nine studies focused on completeness of documentation and typically reported that CDS was associated with significant improvements in documentation. However, nine studies reported that CDS was not associated with improvement in adherence to clinical guidelines.

Of the thirteen studies in our initial review that reported an association of CDS with improvements in adherence to clinical guidelines, five were RCTs. The first, a cluster RCT, evaluated the effects of clinical reminders and structured documentation templates on adherence to attention-deficit/hyperactivity disorder (ADHD) guidelines, and found that guideline adherence was 17 percent higher (53.9 percent vs. 70.9 percent) in the intervention group than in the control group.¹⁶ Another RCT evaluating the effects of CDS alerts on diagnosis rates of gastro-esophageal reflux disease (GERD) found that the odds of GERD diagnosis increased by 33 percent in the intervention group and that the odds of diagnosis and treatment of GERD among the subset of patients with atypical symptoms increased by 102 percent and 40 percent respectively.¹⁷ The third RCT, a cluster RCT of alerts and reminders to promote adherence to

asthma guidelines, reported that the use of controller medications, spirometry, and up-to-date care plans were six percent, three percent, and 14 percent higher, respectively, in the intervention practices.¹⁸ The fourth RCT reported that a vascular risk CDS system was associated with significantly higher rates of improvement of a composite measure of process quality (an average difference of 4.70 on a 27-point scale over controls).¹⁹ Finally, in the fifth RCT, a CDS system embedded in an EHR modestly reduced inappropriate antibiotic prescriptions among adults (-0.6 percent) and had a substantial impact on changing the overall prescribing of broad-spectrum antibiotics among pediatric (-19.7 percent) and adult patients (-16.6 percent).²⁰

Eight other studies, which employed a variety of study designs to evaluate the effect of CDS on guideline adherence reported positive results across a number of different conditions. The first study evaluated the effects of a documentation template within a commercial EHR on documentation of asthma severity and the appropriate use of inhaled corticosteroids. The study found that documentation of asthma severity increased by 20 percent (from 24 percent to 44 percent), and that the use of inhaled corticosteroid increased more than 34 percent (from 36.7 percent to 71.1 percent).²¹

The second study reported that EHR-based notification of pathology results improved the proportion of patients who received follow-up at 6 months (OR 0.7 pre-intervention vs. post-intervention).²²

In the third study, an EHR-based CDS tool for management of depression in primary care was associated with increased use of standardized tools for depression diagnosis (80 percent vs. 47 percent) and monitoring (85 percent vs. 27 percent).⁸

In the fourth study, a CDS intervention significantly improved adherence to a number of hypertension best practices in four community health centers;²³ and another, fifth, study using national data reported that blood pressure control was significantly better in visits where both EHR and CDS (79 percent) were used, compared to visits where neither tool was used (74 percent).²⁴

In a sixth study, CDS alerts were associated with a five percent absolute improvement in the rate of anticoagulation monitoring (39 percent vs. 34 percent).²⁵

In the seventh study the authors reported that CDS alerts were associated with a 46.2 percent absolute increase in the number of prenatal patients who received all guideline recommended care, and that the percentage of patients receiving recommended care dropped 38.6 percent after the CDS alerts were deactivated.²⁶

In a descriptive study, the authors reported that clinicians accepted 4.2 percent of alerts from an automated EHR-based CDS system to ensure appropriateness for GI endoscopy and sedation. The authors concluded that use of the CDS system may have improved adherence to best practices, but the low rate of alert acceptance indicated provider alert fatigue.²⁷

Nine studies evaluated the effects of CDS on documentation. The first, an RCT conducted across19 ambulatory practices in the UK, found that CDS alerts increased the number of patients

with complete documentation of cardiovascular risk factors by 1.94 percent (2.97 percent vs.1.06 percent), but that the intervention was not associated with a reduction in the rate of cardiovascular events.²⁸ The second study evaluated the effects of CDS on the documentation of risk factors for tuberculosis and iron-deficiently anemia, and found that documentation rates were 14.1 percent higher for iron-deficiency anemia risk factors (17.5 percent vs. 3.1 percent) and 1 percent higher for tuberculosis risk factors (1.8 percent vs. 0.8 percent) in the intervention group than in the control group.²⁹ Three studies reported that CDS alerts were associated with significant relative increases in the documentation of weight status, ranging from 12 percent to 49 percent.^{7, 30, 31} An RCT reported that providers exposed to CDS alerts were significantly more likely to document problems on the problem list (adjusted OR=3.4) than controls.³² Finally, three other studies reported that CDS alerts were associated with increased documentation of brief alcohol interventions among veterans with a history of alcohol misuse (from 5.5 percent to 29 percent);³³ depression screening and referral rates for depression assistance among new mothers (2.4 percent vs. 1.2 percent);³⁴ and documentation completeness among diabetes patients.³⁵

Nine studies reported that CDS did not result in clinically meaningful improvements in care processes. In several of these studies, the authors concluded that low utilization limited the effectiveness of CDS. The first study, an RCT that tested CDS for appropriate antibiotic prescribing among children, found no difference in total antibiotic utilization in the control and intervention groups.³⁶ The second study evaluated CDS in the Veterans Health Administration (VA), and reported that a CDS reminder for brief alcohol counseling in primary care was not associated with an increased rate of alcohol counseling or significant resolution of unhealthy drinking.³⁷ Researchers from the VA also evaluated how often alerts that point to abnormal lab test results were ignored or response was delayed. They reported that 10.2 percent of alerts went unacknowledged and 6.8 percent lacked timely follow up. The authors concluded that safety risks remain even in highly computerized environments.³⁸ Similarly, despite the presence of guideline-based CDS alerts, fewer than 13 percent of eligible patients received screening for abdominal aortic aneurysm.³⁹

Another RCT investigated the effects of CDS for non-steroidal anti-inflammatory drugs in primary care, and reported that adherence to guidelines was 3 percent greater in the intervention group than in the control (25.4 percent vs. 22.4 percent). However, the authors concluded that this improvement was not likely to be clinically meaningful, and that poor alignment with clinical workflows and physician disagreement with the guidelines likely undermined the effectiveness of the CDS.⁴⁰

Other studies that evaluated the impact of CDS reported neutral results. One study reported that the implementation of a CDS alert to increase appropriate implantable device use in heart failure patients was not associated with significant increases in the adherence to practice guidelines.⁴¹ Non-interruptive CDS alerts were not associated with increased nephrologist referral or urine albumin quantification among patients with mild to moderate chronic kidney disease,⁴² nor did CDS alerts significantly increase risk-appropriate care for patients with chest pain in primary care settings,⁴³ or improve smoking cessation medication prescription.⁴⁴

Alerts and Reminders: Preventive Screening

Representative studies of the effects of preventive screening health IT interventions include eighteen studies evaluated the effects of CDS alerts and reminders to improve preventive screening. Ten studies focused on CDS alerts and reminders targeted to providers, and eight focused on alerts and reminders for patients. Seventeen of the18 studies reported positive or mixed-positive results; however, in some cases the authors concluded that CDS alerts were not sufficient alone to have meaningful impact, and two studies demonstrated that the effects of CDS were significantly enhanced when combined with care process innovations such as panel management. In addition, low rates of adoption and use hampered the effectiveness of health IT interventions that targeted patients.

Like provider-targeted alerts for guideline adherence, alerts for preventive screening were effective across a range of conditions. The first study reported that CDS within a commercial health IT system improved osteoporosis screening rates by 4 percent (80.1 percent to 84.1 percent) in a pre-post study, a statistically significant improvement.⁴⁵ In the second study, researchers implemented a guideline-based alert in a commercial EHR for alpha(1)-antitrypsin deficiency (AATD), and found that the alert increased the rate of AATD screening by 10.4 percent (15.1 percent vs. 4.7 percent); however the increased testing did not produce a significant increase in the AATD detection rate.⁴⁶ Another study of commercial CDS reported that the rates of abdominal aortic aneurism screening increased 12.6 percent (31.4 percent to 44 percent) after the intervention.⁴⁷ A CDS alert for post-stroke depression (PSD) was associated with a 4.8-fold increase in the odds of PSD screening and a 2.5-fold increase in the odds of treatment action among those who screened positive.⁴⁸

A relatively limited EHR was positively associated with improvement on five of 11 women's preventive healthcare measures, and the results of the same analysis suggested that more sophisticated EHRs were associated with higher rates of women's preventive healthcare tests and exams.⁴⁹ EHR-based CDS alerts significantly increased testing of Chinese and Vietnamese patients for hepatitis B virus when compared to "usual care" (40.9 percent vs. 1.1 percent).⁵⁰ A CDS alert was associated with a 19 percent increase in vaccination rate (61 percent vs. 42 percent) among obstetric patients.⁵¹ Finally, an EHR-based screening tool for bipolar disorder was associated with increased detection of bipolar disorder (1.1 percent vs. 0.36 percent) and prescription of appropriate medications (1.85 percent vs. 1.19 percent).⁵²

An RCT in Australia evaluated CDS alerts for chlamydia screening and reported that the intervention increased screening rates by 27 percent over those of the control group.⁵³ However, the authors concluded the CDS alerts alone were not likely to raise screening levels enough to affect the burden of chlamydia in the population, but that they could be a key part of a more comprehensive intervention.

A three-arm RCT evaluated the effects of CDS screening reminders alone and combined with panel management, compared to a control group, on adherence to guidelines for bone density screening and recommended vaccines. The authors reported that bone density screening was completed in 17.7 percent of patients in the control arm, 19.7 percent in the CDS reminder arm, and 30.5 percent in the CDS reminder plus panel manager arm. Pneumococcal vaccine was given to 13.1 percent of patients in the control arm, 19.5 percent in the CDS reminder arm, and 25.6

percent in the CDS reminder plus panel manager arm. Influenza vaccine was given to 46.8 percent of patients in the control arm, 56.5 percent in the CDS reminder arm, and 59.7 percent in the CDS reminder plus panel manager arm. All results were statistically significant, suggesting that the effects of CDS reminders can be significantly enhanced when coupled with care practice redesign.⁵⁴

Eight studies focused on patient reminders and patient registries. The first study, a cluster RCT, found that patient reminders resulted in mammogram screening rates 8.1 percent higher in the intervention group than in the control group (23.3 percent vs. 31.4 percent).⁵⁵ Two other controlled studies found that patient reminders significantly increased osteoporosis and colorectal screening 7.4 percent and 8.3 percent respectively.^{56, 57} However, in the case of colorectal screening, the difference between the intervention group and the control group was short-lived, as the screening rates in the two groups were not significantly different after four months of follow up. Other studies reported that patients with access to the PHR were 6.7 more likely to receive influenza vaccination,⁵⁸ and that PHR-based reminders were associated with increased rates of screening mammography (48.6 percent vs. 29.5 percent) and influenza vaccinations (22.0 percent vs. 14.0 percent), but not bone density testing, cholesterol testing, pap smear, or pneumococcal vaccination.⁵⁹

Two other studies illustrated how low uptake and missing or invalid data limit the effectiveness of patient-targeted health IT interventions. In the first study, patients who adopted a PHR were nearly twice as likely to be up to date on recommended preventative services as patients in the control group (25.1 percent vs. 12.6 percent). However, fewer than 17 percent of the patients in the intervention group used the PHR.⁶⁰ Among patients in a state immunization information system (IIS), reminders were positively associated with seasonal influenza vaccination. However, more than 40% of children assigned to receive a reminder were determined to have an invalid or undeliverable address.⁶¹ A third study reported an unintended consequence of patient-targeted alerts and reminders. In an evaluation of a CDS intervention to increase colorectal cancer screening among high-risk patients, the researchers observed a 2.2 percent decrease in the likelihood of adherence to colorectal cancer screening guidelines among the recommended patient population. The authors hypothesized that the counter-intuitive result was due to a shift of limited colonoscopy capacity from average-risk screening to higher-risk screening, or due to alert fatigue.⁶²

Multifaceted Health IT Interventions

Fourteen studies evaluated the effects of multifaceted health IT interventions on process quality. Eight studies found that multifaceted health IT interventions were associated with some improvements in process quality. However, six studies reported that health IT was not associated with improved process quality.

Representative studies of the effects of multifaceted interventions include seven studies of multifaceted health IT interventions that reported positive or mixed-positive results, the first study, a time series study of a multifaceted, commercial health IT-enabled quality improvement intervention found that nine measures of process quality improved significantly more in the year after the intervention than they did during the previous year. Increases ranged from 3.2 percent

improvement in the percentage of patients with coronary heart disease who had a prescription for an ACE inhibitor or ARB to 18.1 percent improvement in the percentage of patients with heart failure who were prescribed anticoagulation therapy for atrial fibrillation.⁶³

A second study, which evaluated an HIV/AIDS-focused health information exchange, reported that the exchange was associated with significant increases in syphilis screening (67 percent to 87 percent) but not with three other indicators of process quality.⁶⁴

A third study, by researchers at a large integrated delivery system, reported that use of an EHRbased population management tool significantly increased compliance to guidelines for diabetes and cardiovascular disease (14.3 percent relative improvement for diabetes 10.6% relative improvement for cardiovascular disease).⁶⁵ Two other studies, conducted in two other large integrated delivery systems, reported that multifaceted health IT interventions were associated with significant improvements in several process quality measures among large populations of diabetes patients.^{66, 67}

Two RCTs evaluated the effects of patient portals in two diverse ambulatory care settings. The first, a cluster RCT of an ADHD patient portal in pediatric practices found that the intervention significantly improved the quality of ADHD care in community-based pediatric settings.⁶⁸ The second, an RCT in adult primary care practices, reported that access to a patient portal was associated with increased adherence to recommended preventive care guidelines (84.4 percent vs. 67.6 percent).¹³

Six studies reported that multifaceted health IT interventions were not associated with positive effects on process quality in ambulatory care settings. One RCT, conducted across 42 primary care practices, reported that EHR use was not associated with better adherence to diabetes care guidelines or a more rapid improvement in adherence to guidelines over three years.⁶⁹ Another study of 155 outpatient cardiology practices reported that implementation of a health IT performance improvement intervention did not achieve greater improvements in quality of heart failure care than practices using paper systems.⁷⁰ In another study, conducted in a single pediatric practice, behavioral health screening rates dropped from 83 percent to 55 percent after EHR implementation, and screening rates did not return to baseline levels until three years post-implementation.⁷¹

Three other cross-sectional studies evaluated the relationship between health IT and standard quality measures using data from large surveys. The first study analyzed data from the National Ambulatory Medical Care and National Hospital Ambulatory Medical Care Surveys and found no consistent relationship between EHRs, CDS, and better process quality.⁷² The second study analyzed data from a survey of 108 California physicians' organizations and reported no correlation between EHR capabilities, composite quality measures for diabetes processes of care, and intermediate outcomes.⁷³ The third analysis, of nearly 3,500 ambulatory visits, reported that the presence of EHR was associated with significantly lowered odds (OR=0.5) that patients with three or more comorbid conditions received depression treatment.⁷⁴

3.3.1.3 Health Outcomes

Seventeen studies included in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on health outcomes in ambulatory care settings. Six studies evaluated CDS interventions for providers, six focused on health IT interventions that targeted both patients and providers, and five focused on multifaceted health IT interventions. Fifteen of the 17 studies reported positive or mixed-positive findings.

Provider Targeted Alerts and Reminders

In this section we describe representative examples of studies that evaluated the effects of CDS on health outcomes in ambulatory care settings. In the first study, the authors reported that the rate of resolution of unhealthy alcohol use was significantly higher in clinics with passive CDS reminders to provide brief alcohol counseling than in control clinics (31 percent vs. 28 percent).⁷⁵ The second study, an RCT of a computer-assisted medication management system for ADHD conducted in pediatric practices, found that use of a medication management software program was associated with greater symptom reduction.⁷⁶ The third study, an RCT of CDS for glucose and blood pressure control among diabetes patients, reported that the intervention was associated with significantly improved hemoglobin A1c and that 5.1 percent more patients in the intervention group had controlled systolic blood pressure (80.2 percent vs. 75.1 percent). However, the CDS was not associated with significant improvements in low-density lipoprotein cholesterol and diastolic blood pressure control.⁶ In the fourth study, implementation of a CDS intervention significantly improved blood pressure control in four community health centers (50.9 percent vs. 60.8 percent).²³ Finally, a study of CDS reminders from the UK reported that the reminders were not associated with a significant reduction in cardiovascular events.²⁸

Patient Targeted Alerts and Reminders

Representative studies of the effects of patient targeted interventions include six studies evaluated patient targeted alerts: All reported positive or mixed-positive results. Two RCTs evaluated health IT interventions that targeted both patients and providers. The first study found that hemoglobin A1c levels decreased significantly more in a group of patients who received mobile application coaching combined with patient portals than in a control group (1.9 percent vs. 0.7 percent).⁷⁷ The second study, also in primary care clinics, involved tailored patient education informed by patients' answers to a questionnaire administered on a touch screen tablet. This study found that the intervention was associated with significant improvements in knowledge, self-efficacy, and behavior regarding adverse self-medication practices among older adults with hypertension.¹²

In our initial review, four studies involved use of PHRs and patient portals. In an RCT, active PHR use was associated with a 5.25 point reduction in diastolic BP; however, only 25 percent of users actively used the PHR.¹⁴ In another RCT, patients who received access to a multifaceted PHR platform achieved greater decreases in HbA1c at six months, but the differences were not sustained at 12 months.⁷⁸ In a third RCT, a web-based eHealth intervention with telephone nurse case management was associated with significantly better asthma control, but not with more days of symptom control, adherence to asthma controller, self-efficacy, or information competence.⁷⁹ Finally, in a descriptive study, use of a PHR was associated with increased likelihood of HbA1c testing (OR 2.06).⁶⁶

Multifaceted health IT Interventions

Representative studies of the effects of multifaceted health IT interventions include two studies evaluated the effects of multifaceted health IT interventions on health outcomes. In an RCT across 49 community-based physician practices, a vascular risk CDS system was not associated with improved vascular outcomes despite significant process quality improvements.¹⁹ A HIE between three clinics was associated with significant improvement in health outcomes among patients with HIV/AIDS.⁶⁴ In another representative study, a large pre-post study of 34 primary care practices in a single healthcare system reported that EHR adoption was associated with significant improvements among diabetes patients.⁶⁷

3.3.2 Non-Ambulatory Care Settings

We identified 69 studies that met the eligibility criteria and assessed the effect of health IT on quality of care in non-ambulatory care settings. Eight studies assessed patient or provider satisfaction, 31 studies assessed processes of care, and 30 studies assessed health outcomes. Evidence Table 2 (See Appendix) presents details for each of the included studies.

3.3.2.1 Satisfaction (Patient and Provider)

Eight studies in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on patient or provider satisfaction in non-ambulatory settings. Five of the studies reported positive or mixed-positive associations.

Representative studies of the effects health IT on patient satisfaction in non-ambualtory care settings include two of studies that evaluated patients' satisfaction with PHR platforms. The first study, an evaluation of the VA's MyHealtheVet personal health record, found high user satisfaction (8.3 on a scale of 1 to 10), that users were likely to return to the site (8.6 on a scale of 1 to 10), and that users would recommend the system to other veterans (9.1 on a scale of 1 to 10).⁸⁰ The second study evaluated satisfaction with a PHR among active duty military personnel. The patients had the option of choosing a PHR provided by either Microsoft Healthvault or Google Health. The authors reported that 91.7 percent of patients were satisfied with the overall functionality of the PHR, but 16.7 percent reported challenges associated with using the PHR.⁸¹

Two other studies evaluated patient satisfaction of health IT used by providers. The first study linked two national hospital data sets, one tracking EHR adoption and the other tracking hospital-level patient satisfaction measures, and reported that EHR were associated with significant increases in three of ten patient satisfaction measures.⁸² The other study evaluated a comprehensive health IT system in a nursing home that included EMR, CPOE, and progress notes among other features. The residents' subjective assessments in the intervention facilities were generally positive.⁸³

Three other studies evaluated providers' satisfaction. A study at a children's hospital evaluated an integrated sign-out system that allowed automatic updates of patient data to facilitate

handoffs.⁸⁴ Satisfaction with the sign-out process increased after the implementation, with staff reporting less time devoted to redundant data entry. A study of CPOE in a single ICU found that ICU clinicians were moderately satisfied with CPOE, and the satisfaction of nurses, but not physicians, increased over time.⁸⁵ Finally, in a study of a barcode medication administration (BCMA) system, 24 percent of pharmacists reported that a the system was "not at all" easy to use, 37 percent reported that BCMA did not improve their job performance, and 52 percent reported that they did not believe the BCMA system improved patient safety. The authors concluded that the primary reason for the poor perception of the BCMA was poor usability.⁸⁶

3.3.2.2 Process Outcomes

Thirty-one studies in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on process measures in non-ambulatory care settings. Five studies focused on order entry, and 19 focused on CDS alerts and reminders; the remaining seven focused on multifaceted and other health IT interventions. Twenty-eight of the 31 studies reported positive or mixed positive findings.

Order Entry

In a controlled before-and-after study, a neonatal pain management module in the CPOE system was associated with a significant increase in the proportion of patients who received a pain assessment (64 percent to 88 percent), and documentation of pain scores also improved.⁸⁷ Another study used an interrupted time series to evaluate the effect of an order set in a commercial health IT system on timely and appropriate discontinuation of postoperative antibacterial prophylaxis and found a 16.9 percent increase in guideline adherence (from 38.8 percent to 55.7 percent) in the intervention group, with no significant change in guideline adherence among controls.⁸⁸ A cross-sectional study of 1300 patients in a single hospital found that CPOE and CDS were associated with a 5.7-fold increase in the odds that patients admitted for acute coronary syndrome received guideline recommended care.⁸⁹ Another study, which evaluated adherence to vancomycin nomogram guidelines in a pre-post study, found a 12 percent increase (from 24 percent to 36 percent) in guideline adherence.

Two studies that evaluated CDS systems that gave guidance for medications reported positive results. The first, a French study, found that guideline adherence for antibiotic prescribing increased 18 percent (from 49 percent to 77 percent) after implementation of computerized clinical guidelines at the time of order entry.⁹¹ The second study, an RCT that evaluated a commercial CDS system for insulin dosing in a burn intensive care unit (ICU), reported a six percent improvement in glucose control in the intervention group over that in the control group. The study also found that nursing staff took more glucose measurements, and that compliance with clinical guidelines was higher in the intervention group than in the control group.⁹²

A pre-post study that evaluated CDS for skin and soft tissue infection control reported that appropriate antibiotic coverage for patients with MRSA increased 9.9 percent (from 86.8 percent to 96.7 percent); however the rate of orders for wound cultures decreased by 31 percent, a result the authors interpreted as a non-positive finding. In addition, the authors noted low use of this CDS system, and suggested the positive results may have been due to more increased awareness than to the tool itself.⁹³ Another study used retrospective chart review to evaluate the effects of

an insulin order set within a commercial health IT system on adherence to guidelines for insulin ordering. The authors reported that guidelines were followed 30.9 percent of the time, a level the authors interpreted as too low to have a clinically meaningful impact.⁹⁴

Alerts and Reminders

Nineteen studies evaluated the effects of CDS alerts or reminders on healthcare process quality measures in non-ambulatory care settings, and 13 of the 15 reported positive findings.

Representative examples include, nine studies evaluated the effectiveness of CDS alerts for a variety of conditions in a diverse set of non-ambulatory settings, and reported positive results. One study that evaluated the effects of vaccine reminders on vaccination rates in a homegrown EHR found that the rates increased 6.6 percent (from 38.8 percent to 45.4 percent).⁹⁵ Another study at the same leading institution found that an automated reminder that identified sub-populations for HIV screening in the ED was well accepted by patients (75.5 percent of patients targeted ultimately agreed to a screening).⁹⁶ A cluster RCT that evaluated adherence to a guideline for recognizing Lynch syndrome for patients recently diagnosed with colorectal cancer showed that high-risk patients were identified 77 percent of the time in the intervention group versus 59 percent in the control.⁹⁷ And in another study, the use of CDS reminders was associated with absolute increases in compliance to infection control precautions between 14 percent and 16 percent.⁹⁸

An EHR-based CDS system for dysphagia screening was associated with significantly increased screening compliance (from 36 percent to 74 percent).⁹⁹ A heparin-induced thrombocytopenia CDS alert was associated with a 33 percent relative increase in thrombocytopenia antibody test orders.¹⁰⁰ Point of care CDS was associated with a 30 percent increase in compliance with surgical infection prevention guidelines in a sample of nearly 20,000 surgical procedures performed in a regional health system.¹⁰¹ A CDS alert targeting patients with severe chronic kidney disease and acute coronary syndrome was associated with a reduced incidence of patients being prescribed contraindicated medications.¹⁰² Finally, implementation of a CDS alert in an inpatient psychiatric unit significantly improved rates of ordering fasting blood glucose and lipid levels.¹⁰³

Other studies evaluated the effects of CDS on clinicians' adherence to guidelines for venous thromboembolism (VTE) prophylaxis: All four reported positive findings. First, a study of a multi-screen CDS alert for VTE prophylaxis for high-risk patients in a homegrown EHR was 7.6 percent more effective than a single screen (58.6 percent of patients receiving prophylaxis vs. 50.8 percent in the control group).¹⁰⁴ Another, pre-post, study in a commercial system assessed the effects of CDS alerts for VTE risk and prophylaxis on VTE and bleeding rates found that the percentage of patients who received VTE prophylaxis increased 10.9 percent (from 25.9 percent to 36.8 percent) and the rate of VTE in medical units decreased significantly (0.55 percent to 0.33 percent), but bleeding rates did not change significantly.¹⁰⁵ Two other studies reported that CDS interventions were associated with significant absolute increases in guideline-appropriate VTE prophylaxis of 3 percent (from 6.6 to 9.6 percent) and 18.2 percent (from 66.2 percent to 84.4 percent) respectively.^{106, 107}

Other studies reported that CDS alerts were not associated with significant improvements in process quality in non-ambulatory care settings. The first, which evaluated tailored clinical reminders in a homegrown system, found that physicians responded to only 43.9 percent of alerts, which the authors interpreted as a negative finding.¹⁰⁸ The second study reported that a CDS intervention was not associated with significant differences in any of the quality measures of geriatric care studied in a single institution regarded as a "health IT leader."¹⁰⁹

Multifaceted health IT Interventions

Representative studies evaluated that the effects of multifaceted health IT interventions on standard quality measures, and generally found small positive associations of health IT with process quality measures. A national study investigated the effect of CPOE on various quality measures and found improvements on two of six quality measures (pneumococcal vaccinations and appropriate antibiotic use).¹¹⁰ Another national study of CDS found small quality gains attributable to CDS.¹¹¹ A survey of Massachusetts providers found no association between access to EHR and HEDIS measures but did find some positive associations were strongest between problem lists and visit notes and radiology result review quality measures relating to women's health, colon cancer screening, and cancer prevention.¹¹² In a pre-post study of hospitals transitioning to EHR systems capable of meeting 2011 Meaningful Use objectives, modest incremental process quality improvements were found between 0.35 percent and0.49 percent; hospitals that transitioned to more advanced systems saw incremental declines of 0.9 percent to 1 percent.¹¹³

A longitudinal analysis of national survey and quality reporting data reported that the availability of a basic EHR was associated with a significant 2.6 percent increase in quality improvement for heart failure. However, adoption of advanced EHR capabilities was associated with significant decreases in quality improvement for acute myocardial infarction (-0.9 percent) and heart failure (-3.0 percent) among hospitals that newly adopted an advanced EHR, and 1.2 percent less improvement for acute myocardial infarction quality scores and 2.8 percent less improvement for heart failure quality scores among hospitals that upgraded their basic EHR. The authors concluded that mixed results may suggest that current practices for implementation and use of EHRs have had a limited effect on quality improvement in US hospitals, but that potential "ceiling effects" limit the ability of existing measures to assess the effect that EHRs have had on hospital quality.¹¹⁴

Another study reported that the implementation of an EHR with embedded CDS that provided antimicrobial recommendations was associated with a 28 percent decrease in antimicrobial utilization as well as significant reductions in the rate of Clostridium difficile and MRSA infections.¹¹⁵ Another analysis of national survey and outcomes data reported that higher overall computerization scores correlated weakly with better quality score for acute myocardial infarction but not for heart failure or pneumonia.¹¹⁶ Finally, one pre-post intervention led to a 10 percent improvement in immunization rates in adults 65 years of age or older and in younger adults with diabetes or chronic obstructive pulmonary disease.¹¹⁷

3.3.2.3 Health Outcomes

Thirty studies in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on health outcomes in non-ambulatory care settings. Twelve focused on CDS alerts and reminders, eight focused on order entry and 10 focused on multifaceted or other health IT interventions. Twenty-one of the 28 studies reported positive or mixed-positive findings.

Alerts and Reminders

Several representative studies evaluated the relationship between health outcomes and alerts and reminders. In the first study, insulin dosing via a computerized protocol in a commercial CDS system was associated with improved glycemic control in a burn unit: Time in target glucose range was 6 percent higher in the intervention group (47 percent vs. 41 percent) than in the control group.⁹² The second study evaluated a homegrown CDS system in a surgical ICU and reported that mortality was significantly less than expected after the implementation of the CDS (24 percent observed mortality vs. 62.5 percent expected mortality).¹¹⁸Å pre-post study of a nurse-centered computerized potassium regulation protocol CDS in a cardiothoracic ICU found hypokalemia decreased 1.7 percent (from 2.4 percent to 1.7 percent) and hyperkalemia decreased 2.6 percent (from 7.4 percent to 4.8 percent).¹¹⁹ In a fourth study, point-of-care CDS was associated with a 0.4 percent absolute risk reduction in the incidence of surgical site infection among nearly 20,000 surgical patients.¹⁰¹ In a fifth study, automated CDS reminders were associated with a significant reduction in postoperative nausea and vomiting incidence in a general surgical population (23 percent vs. 27 percent) in a single hospital.¹²⁰ Finally, two studies reported that CDS alerts for VTE prophylaxis were associated with significant reductions in VTE rates and preventable harm.^{106, 107}

A few studies did not find positive associations between CDS alerts and health outcomes. Including, An EHR-based CDS system implemented at a single site for dysphagia screening was not significantly associated with any improvement in hospital mortality or pneumonia rates among stroke admissions.⁹⁹ Nor was a heparin-induced thrombocytopenia CDS alert associated with improved antibody-positive test rate, length of stay, or mortality in a controlled before and after study at a single site.¹⁰⁰ Finally, a controlled trial involving 80 patients found that a CDS alert targeting patients with both severe chronic kidney disease and acute coronary syndrome was not associated with a reduced incidence of in-hospital bleeding.¹⁰²

Order Entry

Several representative studies evaluated the relationship between health outcomes and CPOE. The first study evaluated a commercial CPOE system with local modifications at an academic children hospital and found the mean monthly-adjusted mortality rate decreased by 20 percent compared with historical controls.¹²¹ The second study, based on national cross sectional survey data, found that CPOE use at the level required by Meaningful Use stage 1 (30 percent of eligible patients) was not associated with hospital mortality rates; however the authors reported CPOE utilization at a level closer to the stage-2 Meaningful Use requirement was associated with a 2.1 percent reduction in mortality among Medicare beneficiaries hospitalized for heart attack and heart failure.¹²²

A retrospective cross sectional evaluation of a CPOE-based protocol for glucose management among diabetic patients reported that CPOE was associated with a significant decrease in excessively high glucose levels without increasing clinically meaningful hypoglycemic events.¹²³ An RCT in a single ICU reported that a computerized insulin dose calculator significantly increased the likelihood that ICU patients' glucose measurements were in the target range compared with those of controls (70.4 percent vs. 61.6 percent).¹²⁴

Other studies reported that CPOE was not associated with improved health outcomes. Including a retrospective study found no association between CPOE and Caesarean-sections or length of stay,¹²⁵ and a neonatal pain management module in the CPOE system was not associated with a significant change in the duration of invasive ventilation or hospital stay or the number of nosocomial infections.⁸⁷

Multifaceted health IT Interventions

Among the studies that evaluated the effects of multifaceted health IT interventions on health outcomes, most reported some positive associations with health outcomes. Examples include, a pre-post study, that reported an EHR implementation was associated with an 18.7 percent decrease in nosocomial Clostridium difficile and a 45.2 percent decrease in MRSA infections.¹¹⁵ The second study analyzed cross sectional data from California hospitals and reported that advanced EHR implementation was associated with 3 percent to 4 percent lower rates of inhospital mortality.¹²⁶ The third study evaluated the effects of providing breast cancer patients access to their lab and imaging results: The authors reported that such access was not associated with increased patient anxiety (a positive finding), nor was it associated with a significant change in self-efficacy(a neutral finding).¹²⁷ In the fourth study, the authors analyzed national survey and outcomes data to find that hospital participation in HIE was not associated with lower hospital readmission rates; however, they also reported that high levels of electronic documentation were associated with modest reductions in readmission for heart failure (24.6 percent vs. 24.1 percent) and pneumonia (18.4 percent vs. 17.9 percent).¹²⁸ The fifth study, a controlled trial of 18 nursing facilities, reported that EHR implementation was associated with significant improvements in residents' range of motion and risk for pressure sores.¹²⁹ Another study evaluated the implementation of EHR and CPOE in ten nursing homes and reported that the implementation was not associated with significant improvement on any standard nursing home outcome measures but was associated with some negative findings on behavioral outcome measures.⁸³

Another study, a pre-post study of a custom built EHR deployed in multiple locations in a geographically dispersed pre-natal care delivery system in Texas, reported no significant changes in fetal outcome measures.¹³⁰ In a pre-post study evaluating nearly 6,000 trauma admissions to a single hospital, EHR was associated with significantly decreased hospital length of stay; ICU length of stay; ventilator days; complications including: acute respiratory distress syndrome, pneumonia; myocardial infarction; line infection; septicemia; renal failure; drug complications; and delay in diagnosis; however, mortality, unexpected cardiac arrest, missed injury, pulmonary embolism/deep vein thrombosis, and late urinary tract infection showed no differences.¹³¹ Another study reported that EHR implementation was associated with a 13 percent decrease in hospital acquired pressure ulcers rates but no decrease in fall rates.¹³² In a study of three EDs, the presence of a prior record in the EHR was associated with lower in-hospital mortality (OR=0.45

and 0.55) among heart failure patients in two of the hospitals.¹³³ Finally, an RCT evaluated the effects of a clinical informatics tool on delirium, falls, and mortality in nursing homes. The study reported a 58 percent reduction in the relative risk for delirium; however, effects on falls, mortality and hospitalization were non-significant.¹³⁴

3.3.3 Summary: All Care Settings

Overall, we identified 145 articles that assessed the effect of health IT on 170 quality-related outcomes in ambulatory and non-ambulatory care settings. Twenty studies assessed patient or provider satisfaction, 103 studies assessed processes of care, and 47 studies assessed health outcomes. Table 3.3.1 summarizes all of the quality related article-outcomes, and Evidence Tables 1 and 2 (See Appendix) present further details for each of the included quality-related studies.

		Article-Outcome Results (percent)			
Outcome Type	Number of Article- Outcomes	Positive	Mixed-Positive	Neutral	Negative
Health Outcomes	47	51.1%	29.8%	17.0%	2.1%
CDS Alerts and Reminders	16	62.5%	12.5%	25.0%	0.0%
Computerized Provider Order Entry	8	50.0%	12.5%	25.0%	12.5%
Electronic Prescribing	0	0%	0%	0%	0%
Multifaceted IT Interventions	12	33.3%	58.3%	8.3%	0.0%
Other Meaningful Use	11	54.5%	36.4%	9.1%	0.0%
Process Quality	103	61.2%	21.4%	12.6%	4.9%
CDS Alerts and Reminders	60	70.0%	11.7%	13.3%	5.0%
Computerized Provider Order Entry	6	83.3%	0.0%	16.7%	0.0%
Electronic Prescribing	1	0.0%	100.0%	0.0%	0.0%
Multifaceted IT Interventions	20	25.0%	45.0%	20.0%	10.0%
Other Meaningful Use	16	68.8%	31.3%	0.0%	0.0%
Satisfaction (Patient and Provider)	20	55.0%	25.0%	10.0%	10.0%
CDS Alerts and Reminders	6	66.7%	16.7%	16.7%	0.0%
Computerized Provider Order Entry	3	0.0%	33.3%	0.0%	66.7%
Electronic Prescribing	1	100.0%	0.0%	0.0%	0.0%
Multifaceted IT Interventions	3	33.3%	66.7%	0.0%	0.0%
Other Meaningful Use	7	71.4%	14.3%	14.3%	0.0%
All Quality	170	57.7%	24.1%	13.5%	4.7%
CDS Alerts and Reminders	82	68.3%	12.2%	15.8%	3.7%
Computerized Provider Order Entry	17	52.9%	11.8%	17.7%	17.7%
Electronic Prescribing	2	50.0%	50.0%	0.0%	0.0%

Table 3.3.3.1 Summary of Quality Related Outcomes by Meaningful Use Functionality

		Article-Outcome Results (percent)			
Outcome Type	Number of Article- Outcomes	Positive	Mixed-Positive	Neutral	Negative
Multifaceted IT Interventions	35	28.6%	51.4%	14.3%	5.7%
Other Meaningful Use	34	64.7%	29.5%	5.9%	0.0%

Table 3.3.1 indicates that more than half of articles that evaluated patient and provider satisfaction reported positive findings. However, it is difficult to draw reliable conclusions about the relationship between patient satisfaction and particular Meaningful Use functionalities given the small number of article-outcomes in each category. Likewise, of the 103 articles that assessed process quality measures, more than 80 percent reported positive or mixed-positive results. However, Table 3.3.1 suggests that studies that evaluated the effects of health IT on health outcomes were more likely to report mixed or neutral results than studies that evaluated process measures. While many of the Meaningful Use functionalities were not evaluated frequently enough to draw reliable conclusions about their effects on the different dimensions of quality. some of the Meaningful Use functionalities were commonly associated with improved quality in a number of different settings, contexts, and for a number of different disease conditions. Approximately 68 percent of these articles reported that the CDS alerts and reminders had uniformly positive effects on quality, and a small fraction, reported that the CDS had negative effects on quality. These data support the conclusion, subject to the limitation of publication bias discussed below, that implementation of CDS is very likely to improve quality, and that it should be possible to implement CDS in many different health care settings.

3.4. Narrative Summary: Health IT and Safety of Care

3.4.1 Ambulatory Care Settings

We identified thirteen studies that met the eligibility criteria and assessed the effect of health IT on safety of care in ambulatory care settings. Five studies evaluated e-prescribing, and five studies evaluated the impact of CDS. The other studies evaluated the impact of EHRs and PHRs. Evidence Table 3 (see Appendix) presents details for each of the included studies. Nine of the twelve studies reported positive or mixed-positive results.

All five e-prescribing studies evaluated the effect of the technology on prescribing errors, and four of the five found statistically significant relative reductions in prescribing error, ranging from 38 percent to 84 percent.¹³⁵⁻¹³⁸ The other e-prescribing study, a cluster RCT of a commercial e-prescribing system, did not report a significant reduction in error rates but did note a statistically significant increase in the rate of callbacks to clinical administrators for clarification in the intervention group (n=83 or 1.89 per week vs. n=32 or 1.45 per week), a negative finding.¹³⁹ The authors noted that the effects of the e-prescribing system were likely undermined by its infrequent use.

All five CDS studies found positive or mixed-positive results. For example, in a pre-post study, CDS alerts for antiretroviral drug interactions were associates with a 77 percent relative decrease in the rate of contraindicated antiretroviral drug combinations.¹⁴⁰ In an RCT, CDS alerts targeting drug side effects reduced the risk of injury by 1.7 injuries per 1000 patients.¹⁴¹ A study that evaluated the effects of CDS on adherence to black box warnings reported that the overall rate of adherence did not significantly change after the implementation of the CDS; however, adherence in certain classes did significantly improve, e.g., non-adherence to drug-drug interaction warnings decreased from 6.1 percent to 1.8 percent, and non-adherence to drug-pregnancy interactions decreased from 5.1 percent to 3.6 percent.¹⁴²

In a time series study, an EHR-based, outpatient pediatric quality improvement intervention was associated with significant improvement in the documentation of medication reconciliation from 0 percent in 2005 to a maximum of 71 percent in 2010.¹⁴³ Another time-series study reported that prescription error rates dropped significantly, from 35.7 per 100 prescriptions at baseline to 21.1 12-weeks after transition to a newer EHR, and to 12.2 per 100 prescriptions 1 year after transition to a newer EHR.¹⁴⁴ In an RCT, use of a PHR was associated with a significant reduction in medication discrepancies (OR 0.71), and a significant reduction in the potential risk for severe harm (RR 0.31).¹⁴⁵ Finally, in a descriptive study of more than 30,000 adult patients, researchers found that pharmacists dispensed 1.5 percent of medications that had been discontinued in the EHR.¹⁴⁶

3.4.2 Non-Ambulatory Care Settings

Thirty-three studies included in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on patient safety in non-ambulatory settings. Twenty-four of these studies reported health IT had positive or mixed-positive effects on medication order entry, dosing, and administration.

The majority of studies reported that health IT for order entry and medication dosing had positive effects across a wide range of medication safety-related outcomes, including: significant reductions in adverse drug events;^{147, 148} wrong patient errors;^{149, 150-151} relative reductions in drug dosing errors ranging from 0.9 percent to 88 percent;¹⁵²⁻¹⁵⁶ a 10 percent increase in adherence to antibacterial medication guidelines;¹⁵⁷ a 17.4 percent increase in the timeliness of medication discontinuation;¹⁵⁸ a 47 percent to 86 percent improvement in dosing conformity for renal drugs;¹⁵⁹ a 16 percent reduction in the number of potentially inappropriate medications;¹⁶⁰ a 37 percent reduction in chemotherapy dosing errors;¹⁶¹ a 6.7 percent reduction in omitted medication doses in a pediatric ICU;¹⁶² significant increases across a number of dimensions of prescription completeness;¹⁶³ significantly improved safety of intravenous haloperidol administration in mentally ill patients;¹⁶⁴ and significantly increased true positive rate for adverse drug event alerts.¹⁶⁵

A small number reported mixed positive results. For example, the implementation of CDS alerts to promote appropriate use of antibiotics was associated with a significant increase in the number of antibiotic stewardship interventions; however, 30 percent of CDS alerts were judged to be redundant or clinically unimportant.¹⁶⁶ And in another study the authors reported that the adoption of commercial CPOE systems in five community hospitals was associated with a 34 percent decrease in preventable adverse drug events (ADEs); however the number of ADEs increased (14.6/100 vs. 18.7/100 admissions) overall. The authors interpreted the mixed finding to indicate that CPOE systems can potentially reduce drug-related injury and harm, but that refinements to commercial CPOE applications are necessary to ensure medication safety.¹⁶⁷

A handful of studies reported that health IT had neutral or negative effects on medication order entry or dosing. The first study, an RCT that compared a commercially available CDS alert to a customized alert for concomitant prescribing of warfarin and non-steroidal anti-inflammatory drugs to a commercial CPOE system, found that the active alert made no difference compared to a passive alert.¹⁶⁸ The second, another RCT by the same authors, evaluated the effect of a hard stop, interruptive medication alert in a commercial health IT system: While the authors reported that concomitant orders for warfarin and trimethoprim-sulfamethoxazole decreased by 43.7 percent, the study had to be stopped early because it was determined that the hard-stop alert resulted in unnecessary treatment delays for a number of patients.¹⁶⁹ Two studies reported high rates of prescribing error despite the presence of CPOE systems.^{170,171} One of these studies reported that clinicians responded appropriately to CDS alerts in less than 20 percent of admissions, and the other study reported that the increased number of non-critical CDS alerts was significantly associated with clinically non-appropriate responses to critical CDS alerts. suggesting alert fatigue.¹⁷¹ Another study found using a simulation tool in 62 representative hospitals, that CDS as implemented would have detected only 53 percent of the medication orders that would have resulted in fatal adverse events, and 10 percent to 82 percent of orders that would have caused serious ADEs.¹⁷² Another study reported that duplicate medication errors increased significantly after implementation of commercial CPOE system (2.6 percent pre, 8.1 percent post), and that many work system factors, including IT design, contributed to the increase in duplicate orders.¹⁷³

We identified a handful of studies that evaluated the effects of health IT for medication administration. Although barcode medication administration (BCMA) and electronic medication

administration records (eMAR) were not included in the original Meaningful Use criteria, they are typically used in combination with CPOE and therefore met criteria for inclusion in this review.

The first study evaluated the risk of patient harm from opioid medication error, and reported that BCMA reduced risk of opioid related adverse events by approximately 50 percent.¹⁷⁴ The second study reported that CPOE combined with barcode labeling was associated with a 74 percent relative decrease in specimen errors in a single ED.¹⁷⁵A third study investigated the effects of CPOE and eMAR in acute care hospitals on the quality of medication administration. Across 11 quality indicators the authors found a 14-29 percent increase in odds of adherence to all but one measure.¹⁷⁶ These three positive findings contrasted with a fourth study evaluating a commercial BCMA system that reported that only 99 of 2,308 (~4 percent) alerts for potential adverse events related to warfarin therapy were clinically meaningful at a large academic medical center.¹⁷⁷

3.4.3 Summary: All Care Settings

Forty-six studies in this review investigated the effects of health IT functionalities on medication safety in ambulatory and non-ambulatory settings. In total, 36 of the 46 studies reported positive or mixed-positive results. As was the case for CDS, these data support the conclusion, subject to the limitation of publication bias discussed below, that implementation of CPOE and e-prescribing is likely to improve medication safety and that it is possible to successfully implement these technologies in many different health care settings. However, alert fatigue was a common negative finding in these studies, and other studies reported that order entry systems did not reduce the medication error rates or failed to identify a large proportion of potentially serious medication errors. These negative studies suggest that it may be important to monitor and regularly evaluate the performance of these systems. Table 3.4.3.1 summarizes all of the safety related article-outcomes, and Evidence Tables 3 and 4 (see Appendix) present further details for each of the included safety-related studies.

		Article-Outcome Results (%)			
Outcome Type	Number of Article- Outcomes	Positive	Mixed-Positive	Neutral	Negative
Safety (Medication)	46	67.4%	10.9%	4.3%	17.4%
CDS Alerts and Reminders	10	60.0%	30.0%	0.0%	10.0%
Computerized Provider Order Entry	25	72.0%	8.0%	4.0%	16.0%
Electronic Prescribing	8	50.0%	0.0%	12.5%	37.5%
Multifaceted IT Interventions	2	100.0%	0.0%	0.0%	0.0%
Other Meaningful Use	1	100.0%	0.0%	0.0%	0.0%

Table 3.4.3.1 Summary of Safety Related Outcomes by Meaningful Use Functionality

3.5. Narrative Summary: Health IT and Efficiency of Care

3.5.1 Ambulatory Care Settings

We identified twenty-five studies that met the inclusion criteria and assessed the effect of health IT on efficiency of care in ambulatory settings. Four studies evaluated health IT's effect on costs, fifteen evaluated health IT's effects on healthcare utilization, and six evaluated health IT's effects on the time burden and timeliness of care. Nineteen of the 25 studies reported positive results.

3.5.1.1 Costs

The systematic reviews by Chaudhry, Goldzweig, and Buntin all concluded that the evidence for the cost effects of health IT was limited.^{1, 2, 4} Lack of evidence of the relationship between healthcare costs and health IT is a gap that persists in the literature, particularly in ambulatory care settings. For this review, we identified only four studies that evaluated the relationship between healthcare costs and health IT in ambulatory care settings. In one cross- sectional study, among physicians with EHRs, those with highly skilled, autonomous staff were seven times more likely to be top performers in terms of quality and cost efficiency than those without such staff.¹⁷⁸ In a pre-post study at a single medical center, a CPOE template for enoxaparin was not associated with reductions in the daily cost of therapy among 400 patients with acute coronary syndrome.¹⁷⁹ A large RCT that involved more than 20,000 patients and evaluated a population-based CDS system reported that the intervention group increased their use of outpatient services and total medical expenditures, whereas similar increases in utilization or medical expenditures were not seen in patients in care settings without CDS.¹⁸⁰

3.5.1.2 Utilization

We identified 15 studies in the recent literature that evaluated the relationship between health IT and healthcare utilization in ambulatory care settings. These studies primarily focused on healthcare utilization in two forms: utilization in the form of patient visits or phone calls, and utilization in the form of diagnostic testing; however, two studies evaluated the relationship

between health IT and generic drug use. Thirteen of these studies reported positive or mixed positive results.

Several of these studies evaluated the effects of health IT on physician visits and phone calls. One study, conducted in Finland, found mixed effects on visit utilization. Over a five-year period, a regional HIE was associated with 3 percent and 1 percent reductions in primary care and emergency department visits respectively, but over the same period of time, specialist visits increased by more than 10 percent.¹⁸¹ Another HIE focused on HIV/AIDS was associated with significant increases in the number of medical visits (OR 1.96) in a pre-post study.⁶⁴

Two studies looked at phone calls as their only utilization outcome metric. The first found that the implementation of e-prescribing was associated with a 22 percent decrease in after-hours calls to an academic-affiliated ambulatory clinic,¹¹ and the second found that the introduction of on-line access test results was associated with a 31 percent decrease in phone calls regarding test results at an urban sexually-transmitted infection clinic.¹⁸² Finally, a population-based CDS system was associated with increased outpatient utilization.¹⁸⁰

Two studies that evaluated PHRs found that adoption of a PHR was associated with increased healthcare utilization. One cohort study reported that the rate of office visits, telephone calls, after-hours visits, ED visits, and hospitalizations increased significantly more among PHR users.¹⁸³ The other, an RCT that involved 742 patients, found that patients with access to the PHR were 11.6 percent more likely to visit a health care provider during the study, which the authors considered a positive result.⁵⁸

The same Finnish study cited above also reported mixed results for the effects of a HIE on utilization of diagnostic tests. The authors reported that lab tests increased by 19 percent whereas radiology exams decreased by approximately 16 percent.¹⁸¹ A cross sectional analysis of nationally representative survey data found that EHR use was not associated with diagnostic utilization for preventative care visits, but was associated with 7.1 percent fewer lab tests, and 7.3 percent fewer radiology orders for pre/post-surgery visits.¹⁸⁴ Another cross sectional analysis of national data reported that physicians' access to computerized imaging results was associated with a 40 percent to 70 percent greater likelihood of an imaging test being ordered.¹⁸⁵ A time series study of a CDS for high-tech diagnostic imaging in Minnesota found that the rate of increase of statewide orders of these expensive imaging tests leveled off after implementation, which suggests the CDS was associated with decreased utilization. The high-tech imaging test rates had been increasing at a rate of 9 percent per year prior to the CDS implementation.¹⁸⁶

Two other studies evaluated the relationship between e-prescribing with decision support and generic drug use. One study found that after a two-year follow up period, generic drug use increased approximately 18 percent more among e-prescribers than among paper-based prescribers.¹⁸⁷ The other study found that an electronic prescribing interface redesign that required extra effort to prescribe branded drugs was associated with a 36.9 percent increase in the number of generic medications prescribed.¹⁸⁸

3.5.1.3 Time and Timeliness

We identified a few representative studies in the recent literature that evaluated the relationship between health IT and timeliness or the time burden of care in ambulatory settings. One study compared the time burden of e-prescribing at the point of care to e-prescribing after care, and hand writing prescriptions. This pre-post study found that it took 69 seconds on average to eprescribe at the point of care, 56 percent longer than it takes to hand write a prescription, and 53 percent longer than it takes to e-prescribe after care.¹⁸⁹ A second study, an RCT that involved clinical scenario simulations, found that nurses who used point of care documentation spent 90 percent more time with their patients. However, whereas the absolute amount of time spent talking to the patient was 39 percent greater than in the control group, the relative amount of time that the nurse spent actually talking to the patient was less on a percentage basis (30 percent vs. 41 percent) and that using the point-of-care documentation was associated with prolonged pauses in which the nurse did not speak to the patient.¹⁹⁰ The third study found that simple and inexpensive reconfigurations to the documentation templates in a commercial EHR system resulted in a 5 percent increase in the number of charts completed within 30 days, which in turn resulted in a substantial increase in the number of billable encounters at an academic-affiliated family medicine clinic.¹⁹¹ A fourth study, laboratory data exchange was associated with a significant reduction in the time that HIV therapies were appropriately changed from 37.7 days to 31.4 days, after a brief period when the time to appropriate therapy increased.¹⁵

3.5.2 Non-Ambulatory Care Settings

We identified 37 studies that met the inclusion criteria and assessed the effect of health IT on efficiency of care in non-ambulatory care settings. Thirteen studies evaluated health IT's effects on healthcare costs, twelve studies evaluated health IT's effects on healthcare utilization, and twelve evaluated health IT's effects on the time burden or timeliness of care. Sixteen of the 30 studies reported positive or mixed positive results.

3.5.2.1 Costs

We identified thirteen studies in the recent literature that evaluated the relationship between health IT and healthcare costs in non-ambulatory care settings.

Representative cost studies include: Six studies reported that health IT was not associated with lower hospital costs. The first study, of 326 California hospitals between 1998 and 2007, found that health IT adoption was associated with 6 percent to10 percent higher costs per hospital discharge. The authors also reported that hospitals with more advanced health IT systems had higher nurse staffing levels and tended to staff more registered nurses and fewer licensed vocational nurses, which may contribute to hospitals' higher cost structure.¹²⁶ A second study by the same authors focused on health IT adoption and cost inefficiency in hospital medical surgical wards. The authors concluded that early stage health IT adoption was associated with greater cost inefficiency in medical surgical wards, whereas more sophisticated health IT systems were not significantly associated with cost efficiency.¹⁹² A third longitudinal study, which merged health IT survey data with Medicare cost reports, found that health IT was not significantly associated with cost efficiency.¹¹⁶ A fourth study, also cross sectional,

did not show significant financial savings or higher nurse productivity in hospitals with more health IT.¹⁹³

Two other studies by the same authors used national data sets to explore the relationship between health IT and costs for pediatric admissions in acute care hospitals. The first study reported that hospitals with CPOE did not have significantly lower costs per pediatric case than did hospitals without CPOE.¹⁹⁴ The second study reported that EMR was associated with an average 7 percent increase in per case cost of pediatric inpatient care (\$146 per discharge).¹⁹⁵

One study reported that HIT adoption was associated with some cost savings. A pre-post study conducted in a 325-bed community hospital, found that transcription costs decreased by 75 percent during the year following implementation of commercial EHR and CPOE systems. The authors also reported a variety of quality and safety improvements that followed the health IT implementation. While this study was limited to a single site, the authors concluded that their study showed that it was possible to reap rapid post implementation benefits from EHR and CPOE, even in an institution that had comparatively low costs prior to the implementation.¹⁴⁷

Two studies of ED care presented conflicting results. In the first study, an ED used their health IT systems to create a registry of frequent, high cost patients and developed care plans based on the data. The study found that the health IT-based care plans were associated with a 24 percent reduction in costs for these patients; however, this study was limited in that care plans were developed for only 36 patients.¹⁹⁶ In the second ED-based study, a comprehensive ED information system was associated with an average increase in charges per discharge of 69.4 percent over a 5-year period. The authors also concluded that the increased revenue capture paid for the initial investment in the health IT in only eight months.¹⁹⁷

Two other studies evaluated the effect of health IT on costs in nursing homes. In an RCT, a CDS system for renal insufficiency in nursing homes was associated with a \$1391.43 reduction in annual costs (7.6 percent net reduction). The authors concluded that this reduction was not enough to cover the costs of the intervention.¹⁹⁸ In a study of 18 nursing homes in three states, cost trends were compared across nursing homes that implemented either (1) EHR with bedside charting and onsite expert nurse clinical consultation; or (2) EHR with bedside charting only; or (3) onsite expert nurse clinical consultation only; or (4) no intervention. The study found that EHR with point-of-care charting and onsite expert nurse clinical consultation was associated with cost increases of 12.5 percent, and that EHR with point-of-care charting alone was associated with cost increases of 9.6 percent. The authors concluded that the increases were most likely attributable to acquisition and maintenance costs as well as on-going staff training.¹²⁹

3.5.2.2 Utilization

We identified twelve studies in the recent literature that evaluated the relationship between health IT and healthcare utilization in non-ambulatory care settings.

Studies of the effects of health IT on inpatient utilization were generally positive in their findings. A study carried out in a single community hospital reported that radiology orders, lab tests, and paper use decreased by 6.3 percent, 18 percent, and 27 percent respectively during the year after implementation of commercial EHR and CPOE systems.¹⁴⁷ In a second study,

implementation of a CPOE-based CDS alert to promote adherence to best practices for red blood cell transfusions was associated with a significant, 48 percent, reduction in transfusions in a pediatric ICU.¹⁹⁹ Another study found that a geographically distributed maternal and child health network using their homegrown EHR and elements of telemedicine to coordinate care for complicated pregnancies significantly reduced the number of maternal health visits to the regional tertiary medical center. Reductions ranged from 14 percent to 31 percent.¹³⁰

Several representative studies evaluated ED-based IT interventions also had generally positive, but more mixed, results. In the first study, electronic prescribing in a single ED was not associated with significant improvements in medication adherence among ED patients.²⁰⁰ Another study of three EDs reported that in two of the three EDs studied, the presence of a prior record in the EHR was associated with fewer laboratory tests (-4.6 percent and -14 percent) and medication orders (-33.6 percent and -21.3 percent).¹³³ A third study in a large integrated delivery system in Israel reported that viewing EHR-based patient histories was associated with a 16.2 percent decrease in the likelihood of single-day inpatient admissions from the ED : The authors indicated that this finding suggested that the EHR contributed to improved admission decisions.²⁰¹ Finally, two small-scale studies both reported that patient registries combined with patient-specific care plans were associated with significant reductions in ED utilization among high-risk patients.^{196, 202}

3.5.2.3 Time and Timeliness

We identified twelve studies in the recent literature that evaluated the relationship between health IT and timeliness and time burden of care in non-ambulatory care settings.

Some studies focused on turnaround times for diagnostic tests and the timeliness of clinical documentation. In one study of turnaround times, the authors reported that mean turnaround times for prothrombin time and international normalized ratio lab tests decreased by 25 percent and 32 percent respectively after the introduction of CPOE in an Australian teaching hospital.²⁰³ Another study found that induction agent turnaround times in a single labor and delivery unit decreased 29 percent after the introduction of CPOE.¹²⁵ Another study showed that after the implementation of automated EHR-generated electronic sign-out documents significantly reduced documentation time for medical residents. Specifically residents reported that they spent less time transcribing information from the EHR into sign-out notes. Six months after the implementation, three percent of residents reported spending more than half of their documentation time on sign-out notes, down from 30 percent at baseline.⁸⁴

A handful of representative studies evaluated the relationship between health IT and ED length of stay (LOS). The first study reported that ED LOS decreased by 23 minutes (~12 percent) at an academic-affiliated ED after the introduction of a commercial CPOE, despite increased boarding for admitted patients.²⁰⁴ A second study analyzed data from the National Hospital Ambulatory Medical Care Survey and found that full function EHR systems were associated with 22.4 percent shorter ED LOS and 13.1 percent shorter treatment time, but not with reduced rates of patients leaving without treatment.²⁰⁵ Another study reported that patient LOS in a pediatric ED increased between 6 and 22 percent on average during EHR implementation, but returned to baseline levels three months after implementation.²⁰⁶ Finally, another study reported no significant difference in ED LOS between the first and last days of resident rotations. The

authors interpreted this finding to mean that use of the ED's clinical information systems was not associated with a significant learning curve for residents.²⁰⁷ However, this particular study design was suspect in that any number of un-controlled for factors could have produced such a result.

Other studies evaluated the effects of health IT on the timeliness of care in the ED, including: a study that reported that electronically delivered prescriptions significantly reduced the median pharmacy wait time for discharged ED patients,²⁰⁰ and another that reported that the implementation of CPOE did not significantly reduce the time to administration of pain medications to patients in a single ED,²⁰⁸ and another study reported that the introduction of an electronic nursing documentation system did not reduce the proportion of time nursing staff spent on documentation.²⁰⁹

3.5.3 Summary: All Care Settings

Overall, we identified 58 articles that assessed the effect of health IT on 62 efficiency-related outcomes in ambulatory and non-ambulatory care settings. Seventeen studies assessed costs, 27 studies assessed utilization, and 18 studies assessed the time burden or timeliness of care. Studies of health IT's effects on efficiency were less likely to report positive results than those that evaluated quality or safety outcomes. However, we believe that the relationship between health IT and outcomes such as healthcare costs and utilization is complicated by the fee-for-service reimbursement system, which inherently incentivizes increased provision of services. In Chapter 4, we discuss these issues further. Table 3.5.3.1 summarizes all of the efficiency related article outcomes, and Evidence Tables 5 and 6 (See Appendix) present further details for each of the included efficiency-related studies.

		Article-Outcome Results (percent)			ent)
Outcome Type	Number of Article- Outcomes	Positive	Mixed-Positive	Neutral	Negative
Cost	17	29.4%	5.9%	29.4%	35.3%
CDS Alerts and Reminders	2	0.0%	0.0%	50.0%	50.0%
Computerized Provider Order Entry	3	33.3%	0.0%	33.3%	33.3%
Electronic Prescribing	0	0.0%	0.0%	0.0%	0.0%
Multifaceted IT Interventions	10	20.0%	10.0%	30.0%	40.0%
Other Meaningful Use	2	100.0%	0.0%	0.0%	0.0%
Utilization	27	59.3%	25.9%	3.7%	11.1%
CDS Alerts and Reminders	4	75.0%	0.0%	0.0%	25.0%
Computerized Provider Order Entry	4	75.0%	0.0%	25.0%	0.0%
Electronic Prescribing	4	50.0%	50.0%	0.0%	0.0%
Multifaceted IT Interventions	5	40.0%	60%	0.0%	0.0%
Other Meaningful Use	10	60.0%	20.0%	0.0%	20.0%
Time & Timeliness	18	38.9.0%	22.2%	22.2%	16.7%

Table 3.5.3.1 Summary	of Efficiency Related	Outcomes by Meaningful	Use Functionality
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	Number of Article- Outcomes	Article-Outcome Results (percent)			
Outcome Type		Positive	Mixed-Positive	Neutral	Negative
CDS Alerts and Reminders	1	0.0%	0.0%	0.0%	100.0%
Computerized Provider Order Entry	7	71.4%	0.0%	28.6%	0.0%
Electronic Prescribing	1	0.0%	0.0%	0.0%	100.0%
Multifaceted IT Interventions	5	20.0%	40.0%	20.0%	20.0%
Other Meaningful Use	4	25.0%	50.0%	25.0%	0.0%
All Efficiency	62	45.2%	19.3%	16.1%	19.4%
CDS Alerts and Reminders	7	42.9%	0.0%	14.3%	42.9%
Computerized Provider Order Entry	14	64.3%	0.0%	28.6%	7.1%
Electronic Prescribing	5	40.0%	40.0%	0.0%	20.0%
Multifaceted IT Interventions	20	25.0%	30.0%	20.0%	25.0%
Other Meaningful Use	16	56.3%	25.0%	6.3%	12.5%

Chapter 4. Discussion

For this updated systematic review of the health IT literature, we evaluated over 12,000 titles. Of that sample, we identified 236 articles that evaluated health IT functionalities that are included in the current federal "Meaningful Use" regulations. Below we summarize and discuss our findings related to the effects of health IT functionalities included in the Meaningful Use regulations on three key aspects of care: quality, safety, and efficiency.

Quality

Seventeen studies in this review investigated the effects of health IT functionalities encompassed in the Meaningful Use regulation on patient or provider satisfaction. The studies evaluated very different health IT functionalities, ranging from provider-targeted CDS to commercially available PHR platforms. These studies generally showed that a small majority of patients and providers were satisfied with the various forms of health IT evaluated in both ambulatory and non-ambulatory settings. These studies suggest that it is possible to implement many forms of health IT in many different settings that will appeal to users, but they also highlight that barriers remain. Increased workload and poor usability were the primary reasons cited for provider dissatisfaction with health IT. Health IT use by providers was associated with some increases in patient satisfaction in two studies, but evidence for the effects of provider-targeted health IT on patient satisfaction is still limited. Patients typically reported high levels of satisfaction with PHRs, patient portals, and other consumer facing health IT; however, despite high reported satisfaction low adoption rates have the potential to undermine the effectiveness of these tools.

Ninety-two studies in this review evaluated the effect of health IT on process quality, making process quality the most frequently evaluated of all the key aspects of care considered in this review. The findings of this large and diverse set of articles suggest a benefit of Meaningful Use functionality for process quality measures. While the great majority of studies reported positive outcomes for process quality measures, not all studies did so, and most studies lacked sufficient detail to determine which factors may have led to the lack of benefit found in those studies. Our review found that single-site studies. Single-site studies also provided more detail about the context and complementary factors that may enhance the efficacy of the health IT or contribute to the success of the implementation. The small number of studies that seemed to account for contextual and complementary factors tended to show that health IT can have significant positive effects on process quality if the technology is implemented in combination with process changes that leverage the capabilities of the health IT.

Forty-two studies in this review evaluated the effects of health IT on health outcomes. The outcomes evaluated in these studies were diverse, and the studies were conducted across a broad spectrum of clinical settings, ranging from primary care to the ICU. The generally positive results support the hypothesis that the effects of health IT are not just limited to improved healthcare processes; they can have a positive impact on health outcomes. However, like the studies of quality processes, most outcome studies do not enhance our understanding of why health IT systems did or did not improve health outcomes.

Safety

Forty-six studies in this review evaluated the effects of health IT on safety. Many studies in this review showed the potential benefit of Meaningful Use functionalities on patient safety in both ambulatory and non-ambulatory settings. The studies we identified focused exclusively on medication safety and fell into two groups: studies that evaluated health IT that targeted the order entry and dosing processes and health IT that targeted the medication administration process. In ambulatory settings, e-prescribing and CDS significantly reduced prescribing errors in many studies. In non-ambulatory settings, findings were generally positive as well, suggesting that health IT could improve the safety of medication ordering, dosing, and administration processes. It is promising that benefits were found for CDS for a wide range of medication safety outcomes. The negative findings suggest caution when implementing "hard-stop" functionality that restricts providers' ability to override alerts, and suggest further that high rates of false positive alerts lead to "alert fatigue" and continue to undermine the usability of some health IT systems.

Efficiency

The prior evidence reviews found limited evidence for the relationship between health IT and costs. This limitation continues to characterize the most recent literature as well. Separating the effects of health IT from contextual factors that may heavily influence healthcare costs also remains extremely difficult. We identified only four new studies that evaluated the relationship between health IT and ambulatory costs and 13 new studies that evaluated costs in non-ambulatory settings.

In the newly identified studies, cost effects ranged from a 75 percent decrease to a 69 percent increase in the targeted costs; however, many of the studies clustered in the range of six percent to12 percent increases in the targeted costs. These findings suggest that layering technology on the existing payment system may not result in lower costs. By design, health IT promotes increased adherence to care guidelines (which often entails providers being reminded to take an action that they might have otherwise omitted), and subsequently makes it easier to document work once it has been done. Given the current reimbursement structures predominant in US healthcare, it is not surprising that some studies show that provider organizations that adopted technology that reminds physicians to provide more services—and makes it easier to document them—charge more on average than provider organizations lacking such technology.

Two studies described in Section 3.4.2.1 provide an excellent illustration of how the effects of health IT on costs depend greatly on the processes and incentives that surround the technology. In the first study, the provider organization leveraged their health IT to identify high risk, high cost patients. The identification was followed by the development of individualized care plans for these patients.¹⁹⁶ In this case, health IT was designed and used explicitly to reduce costs and was successful. In the second study, health IT was designed and used to increase revenue capture and was also successful.²¹⁰ If health IT is designed and used to accomplish specific goals related to cost efficiency, some evidence suggests that it can successfully reduce health care costs. However, if health IT is designed and used to enhance revenue capture, then we can also expect that it could be successfully used to increase healthcare costs. As long as fee-for-service, which inherently incentivizes increased services, remains the dominant model of payment, provider organizations are more likely to adopt technologies that will enhance revenue capture. Thus, we

are not likely to see many studies that demonstrate that health IT can be used to significantly reduce healthcare costs until payment systems are realigned to incentivize value rather than volume.

As with healthcare costs, the relationship of health IT with utilization is complicated by the feefor-service payment models that dominate US healthcare. Our review of the recent literature identified some large studies that reported that both patient and provider access to health IT were associated with increased healthcare utilization in the form of more office visits and more diagnostic testing. However, counterbalancing these few studies are several other studies that suggest that health IT can have the opposite effect. Overall, 15 of 19 studies reported that health IT had positive or mixed positive effects on utilization. However, in some cases researchers considered increased utilization to be a positive outcome. While the contextual factors described in the previous section make it difficult to draw definitive conclusions about the relationship between health IT and healthcare utilization, the most recent evidence suggests that in the right context and when incentives are appropriately aligned, health IT can have positive effects on healthcare utilization.

In the recent literature, studies of the time burden and timeliness of care evaluated a number of different outcomes across a variety of care settings. Nine studies reported that health IT was associated with positive or mixed-positive results. Positive findings included shorter ED LOS, reduced diagnostic turn-around times, shorter time to the initiation of appropriate therapies, and more in-person time with patients. Nevertheless, some studies found that health IT was associated with increased workload and time burden for documentation, and that in some instances when providers were able to spend more time with patients, much of that time was spent interacting with the computer rather than the patient. The findings of the current review are similar to those of the previous reviews. Chaudhry reported mixed results from six studies related to health IT and its effects on provider time,¹ and Goldzweig identified increased administrative workload as a frequently cited barrier to health IT adoption.²

Assessments of the efficiency of health IT adoption face a number of challenges. One of these is identifying what the health IT system is designed to do and the way health care is paid for in the environment where the health IT is being implemented. If health care is paid for via fee-forservice, an IT intervention designed to increase revenue capture may lead to increased costs, and be regarded as successful. Similarly, in a fee-for-service environment if a health IT system has CDS designed to alert providers to deliver more recommended care, like increasing influenza vaccinations, increasing colonoscopy, or increasing the use of certain pharmaceuticals, then from the short-term perspective health care costs will increase. Indeed, the health care savings that may accrue from increasing recommended care, such as a hospitalization for influenza pneumonia avoided, or a case of metastatic colon cancer or myocardial infarction that did not occur, may not accrue for many months or years after the recommended care was delivered, and furthermore may be very difficult to detect without population-based data. The savings from these averted cases, in a fee-for-service payment system, may not be reaped by the same party that paid for the care months or years ago. Thus, without a population-based perspective, it is always going to be more feasible to measure the costs associated with health IT implementation, in terms of hardware and implementation and initial decreases in physician productivity and increases in the use of recommended care, than it is to measure the health care savings that

accrue from outcomes averted or more coordinated, less duplicative care. Thus, drawing broad conclusions from studies of the efficiency of health IT implementation must be done with great caution.

Limitations

The primary limitation of this review is the quality and quantity of the available studies. Understanding the effects of health IT requires knowledge of several components, including the following:

- technical factors, i.e. the health IT system itself and other IT systems with which it interfaces
- human factors, including project management skills
- organizational factors, including an organization's past and current culture of change, and its financial context.

In our two previous reviews, this information was largely absent from most of the published studies of health IT. Unfortunately, little has changed in the newest set of health IT-centric hypothesis-testing studies. While there is a rich (primarily qualitative) literature that describes factors that are key to the success of health IT implementations, his literature is primarily distinct from the literature that focuses on the effects of health IT on key aspects of care. Word count limits may discourage authors of studies that focus on the effects of health IT from including important contextual information in their published reports. In addition, rich contextual data are difficult to collect and particularly absent in state or national-level data sets that are often used to evaluate the effects of health IT among large groups of health IT, researchers should make greater efforts to capture these data and incorporate them into their studies; and journal reviewers should consider whether authors adequately accounted for technical, human, and organizational factors in their studies when evaluating articles for publication in their journals.

The second limitation is that, while our search efforts were comprehensive, we may not have found all the relevant studies. We selected only articles classified as hypothesis-testing studies that evaluated the effects of health IT functionalities comprised in the Meaningful Use regulation on three key aspects of care. These articles tend to have less description about how the health IT actually operated and its implementation processes than do qualitative descriptive articles, although in general we did not find good evidence of such critical information during our review processes. We also note that while these qualitative articles might contain more contextual information about the health IT systems, they are completely lacking in any generalizable knowledge about the benefits of health IT such as reduction in errors or quality improvement. Any studies that compared outcomes (such as error rates) with and without a health IT system would have been classified as hypothesis-testing studies and thus included in our analyses. However, it is conceivable that there may be descriptions of contextual and implementation factors that could be linked with hypothesis-testing studies of the same systems that are described in separate publications.

A third limitation is that we considered only published studies. The nature of scientific publishing is such that potentially illustrative experiences of some healthcare organizations with

commercial health IT systems are neither published in scientific journals nor publicized in any other way. Therefore, we know that relevant experience is going unreported; more needs to be done to encourage publication of these experiences. A useful example that deserves emulation is the Agency for Healthcare Research and Quality funding to academically-trained health services researchers to study the implementation of a commercial health IT system in the Baylor Health Care system; such an evaluation has yielded useful insights on the costs and outcomes of health IT systems in real-world care.

A fourth limitation is that many of the studies were specific to one clinical condition or setting and therefore may not be generalizable for every application of the functionality. For example, the impact of CDS may vary quite a bit by condition. Future studies should try to understand the success factors for HIT functionalities across disease conditions.

A fifth limitation is that many of the costs and financial benefits of health IT will change over time because they depend on dynamic factors such as hardware, software, and labor costs as well as time and region-dependent factors that determine the costs of medical services. Consequently, it is difficult to generalize cost effects.

Chapter 5. Conclusions

Overall, we found that the majority (~78 percent) of research articles reported positive or mixedpositive results regarding the effects of health IT. We performed a number of statistical analyses to determine whether the likelihood of reporting positive results varied significantly across different settings, Meaningful Use functionalities, outcome types, or commercial vs. homegrown health IT systems. Neither study setting, recognition as a health IT leader, nor commercial status was significantly associated with outcome results. However, results differed across the different outcome types and Meaningful Use functionalities: Studies of efficiency were less likely to report positive results than studies of safety or quality (see Table 3.2.6), and studies that evaluated e-prescribing and multifaceted health IT interventions were less likely to report positive results than were studies of CDS or CPOE (see Table 3.2.7).These two findings are likely related because e-prescribing studies often evaluated efficiency outcomes.

We also observed that studies of CPOE and CDS were typically narrowly focused, i.e., they evaluated a single alert or ordering template that focused on improving adherence to a particular guideline. However, studies that evaluated multifaceted health IT interventions tended to be more broadly focused in terms of both the interventions studied and the outcomes evaluated. This observation is consistent with a systematic review by Greenhalgh, who concluded that smaller health IT interventions were more often more successful than larger interventions.²¹¹

We identified two broad themes. The first is that the published literature on health IT is expanding rapidly, and most of this expansion is attributable to commercial health IT systems. Goldzweig identified 179 eligible studies in the 3 years of time covered by their review. We identified more than 230 eligible studies over a similar time period using narrower inclusion criteria. Even more remarkable is the increase in studies about commercial health IT systems. In the original review by Chaudhry and colleagues, studies of commercial IT systems constituted a negligible proportion of the literature (less than 5 percent), and even in the review by Goldzweig and colleagues this proportion had increased to only about 8 percent. By contrast, in the current review, more than 50 percent of the eligible studies were explicitly about commercial health IT systems, a more than 600 percent increase in studies of commercial health IT systems over the prior 8 years.

The second broad theme is that, with some notable exceptions (see below), much of the health IT literature still suffers from methodological and reporting problems that limit our ability to draw firm conclusions about why the intervention and/or its implementation succeeded or failed to meet expectations, and their generalizability to other contexts. For example, drawing cause-and-effect conclusions about health IT from studies that use a cross-sectional design is usually not justified, and although the number of such studies in the current view is only half that of the Goldzweig review, about 10 percent of eligible studies still attempt to draw conclusions about the effects of health IT using cross-sectional designs. An even more pervasive limitation is the lack of reporting about key elements of context and implementation of health IT, regardless of study design. This limitation was noted in Chaudhry's review, and despite calls then and since for better reporting on context and implementation, and even suggestions for specific items to report on,²¹² we still find that crucial elements of context and implementation are missing from the majority of published health IT studies. For example, understanding an organization's

financial context, in terms of its mix of payers and the competitiveness of the local health care marketplace, is crucial to understanding the business case for health IT and its potential effects on efficiency and health care costs. Yet this information was missing from the vast majority of studies. Similarly, reporting on key implementation items such as how much and what kind of staff education and training were performed, the use of local champions and helpdesk support are crucial to understanding "how to make it work." Yet again, most of this information was missing from the majority of articles, making it difficult to differentiate between lack of success due to failures in concept and lack of success due to failures in implementation.

We expect the trends identified in the first broad theme to continue. The continued increases in the volume of literature will make reviews such as this one a) more necessary, since individuals will be unlikely to keep up with all the literature on their own; b) more frequent, since the changes are happening rapidly; and c) more challenging to perform. The vast increase in the number of titles that need to be screened to find eligible studies makes traditional methods of systematic reviews extremely time consuming. In this review, we have experimented with machine-learning methods to try to improve the efficiency with which eligible studies were identified. Our results are encouraging, and continued work on machine-learning methods is warranted if systematic reviews on health IT are to be kept up-to-date.

For the increased literature on health IT to have its maximal impact, more progress must be made on the problems identified in the second broad theme, study design and reporting. Studies of health IT must be designed, conducted, and reported in such a way that stakeholders can better understand what aspects of the results were specific to the context or the organization that was the setting for the health IT assessment, and how other organizations can replicate or improve on those results. Related to this requirement is the need for better studies of the broader effect of health IT implementations. As noted by Lilford and colleagues, policy and service interventions (which include implementation of health IT) can have both "narrow" and "diffuse" effects.²¹³ Thus, CPOE can narrowly target adverse medication errors, and CDS can narrowly target certain processes of care for certain clinical conditions. However, within a hospital, thousands of actions occur each day, many of which may be influenced by a policy or service intervention such as an EHR (some in ways that may not be anticipated or even possible to explicate a priori), and "the effect of each clinical process might be so small that impracticably large samples would be required to avoid high probabilities (or the near certainty) of false null results,"²¹³ if the outcome being assessed was a narrow one. According to Lilford and colleagues, these numerous smaller clinical processes converge on outcomes that have the potential to be placed in discrete and identifiable groups. These outcomes then encapsulate the net effect of service or policy interventions on many individual processes. Thus, while it is conceptually easier and more feasible to study in a clinical trial a narrowly targeted IT implementation, such as a CDS to improve heparin dosing or an alert to improve preventive care, there is a need to foster the more challenging studies that examine the diffuse effects of health IT. Without such studies, we will tend to base conclusions about the effects of health IT primarily on studies examining narrow targets and will miss the potential effects on broader outcomes. For the reason, there are more studies - and stronger conclusions possible - for health IT's effects on narrow targets like adverse drug events and preventive care than there are for diffuse outcomes like efficiency.

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Appendix

Web Based Questionnaire

RAND researchers conducted the first systematic review of the health IT literature (Chaudhry, et al. 2006). This review included articles published between 1995 and 2004. A second review, also conducted by RAND (Goldzweig, et al. 2009) used similar methods to systematically review articles published between 2004 and 2007, and the latest review (Buntin, et al. 2011) conducted by researchers from the Office of the National Coordinator for health IT (ONC), was an explicit update of the previous two reviews conducted. In each case, these systematic reviews looked broadly at clinical health IT and did not focus on a specific patient population, clinical outcome, or health IT functionality. ONC has requested that RAND update this series of systematic reviews and adopt a similarly broad focus.

Even with their broad focus our systematic reviews have been guided by "key questions", which ultimately determined how the research findings were organized. Examples of the "key questions" for the first systematic review were:

1. What does the evidence show with respect to the costs and benefits of health information exchange for providers and payers/purchasers?

2. What knowledge or evidence deficits exist regarding needed information to support estimates of cost, benefit and net value with regard to health IT systems? Discuss gaps in research, including specific areas that should be addressed, and suggest possible public and private organizational types to perform the research and/or analysis.

3. What are the barriers that health care providers and health care systems encounter that limit implementation of electronic health information systems?

The two more recent systematic reviews made it clear that the health IT literature has evolved. Therefore, the key questions for this systematic review need to evolve as well. For example, the concept of "Meaningful Use" of health IT did not exist in 2005, but is now a topic of great interest to ONC and other stakeholders.

As a member of our technical expert panel we would like your input on what key questions should guide this updated systematic review. The key questions will help us determine the most intuitive and effective ways to organize our findings, e.g., should our findings be organized around the functional concepts laid out in the "Meaningful Use" regulations or would they be more effectively grouped by the types of outcomes observed?

As a first step towards crafting our key questions, we would like you to help us prioritize a list of topics that we think might be of interest. We have divided the topic areas into two broad categories: health IT functionalities (Question 1) and health IT associated outcomes (Question 2). As you make your choices we ask that you consider both the importance of the topic as well as the likelihood that there is evidence to be found and synthesized. Ideally we would like to

avoid topics where there are very few studies. Equally important we ask that you provide suggestions for important topics that we should focus on that are not listed below.

Finally, in addition to reviewing studies that have been published in the peer reviewed literature ONC has asked that we conduct an "environmental scan", i.e., that we review studies or reports that have been published by professional or trade organizations outside of the peer reviewed literature. We have compiled a list of organizations that we have considered including in our scan. We would like your feedback on the list of organizations that we have compiled.

1. The following topics are related to the functionality of health IT. Please rank the following health IT functionality topic areas in order of importance

	Rank
Meaningful Use	_
Certified EHR technology	•
Health information exchange	_
Electronic prescribing	•
EHR Usability	_

2. The following topics are related to patient or process outcomes that may be associated with the use of health IT. Please rank the following topic areas in order of importance.

	Rank
Medication Safety	-
Patient Safety (separate form medication safety)	
Care coordination	•
Chronic Disease Management	-
Efficiency of healthcare delivery	-
Heart Disease & Stroke outcomes (including intermediate outcomes: asprin therapy, smoking cessation, cholesterol/blood	•

pressure control patient safety)

3. Please provide us with additional topics or specific questions you think our systematic review should focus on

Literature Search Strategy

Search Terms

"health information" OR "clinical data exchange" OR "exchange of clinical data" OR electronic health record* OR electronic medical record* OR "computerized physician order entry" OR "computerized provider order entry" OR cpoe OR "electronic medication administration" OR emar OR electronic prescription* OR "electronic prescribing" OR eprescription* OR e prescribing OR e-prescription* OR e-prescribing OR "electronic notes" OR "electronic documentation" OR bar code* OR ipad OR "patient portal" OR "social media" OR mobile device* OR mobile phone* OR mobile telephone* OR cellular phone* OR cell phone* OR "Medical Order Entry Systems" [Mesh] "personal health record" OR phr[tiab]

NOT protein OR "probable high risk"

AND

cost OR costs OR economic* OR efficien* OR satisf* OR safety OR "patient access" OR quality OR "Meaningful Use" OR evaluat* OR "coordination of care" OR "co-ordination of care" OR care transition* OR hand-off* OR decisionsupport OR "decision support" OR reminder* OR adverse OR harm* OR outcome*

OR

automatic data processing[majr] OR medical informatics[majr] OR medical informatics applications[majr] OR public health informatics[majr] OR electronics, medical[majr] OR "information technology" OR "information technologies" OR "information infrastructure" OR ehealth OR e-health

AND

"Costs and Cost Analysis"[Mesh) OR "Economics"[Mesh] OR cost[ti] OR costs[ti] OR economic*[ti] OR efficien*[ti] OR satisf* OR safety OR "patient access" OR quality OR "Meaningful Use" OR evaluat*[ti]

OR

"coordination of care" OR "co-ordination of care" OR care transition* OR hand-off* OR decision-support OR "decision support" OR reminder* OR adverse OR harm* OR outcome*[ti] OR outcome and process assessment[mh]

NOT

imaging OR radiograph* OR "ct scan" OR mri OR magnetic resonance OR tomograph* OR imrt OR robot* OR vivo OR vitro OR situ OR simulat* OR driving OR driver*

NOT

(letter[pt] OR editorial[pt])

Abstract Screening Form

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- 1. What is this study about?
 - No HIT as critical part of study [exclude]
 - Not relevant to clinical care [exclude]
 - Commentary, non-systematic review, or other non-research study [exclude]
 - Context of HIT (for background section) [exclude]
 - Telemedicine routine SMS reminders
 - Telemedicine more sophisticated than routine SMS
 - Consumer HIT [exclude]
 - Meaningful use HIT
 - Advanced HIT (e.g. alerts, dashboards, reminders)
 - Attitudes, barriers/facilitators toward HIT

Clear Response

2. What methods were used?

- Randomized Controlled Trial
- Non RCT hypothesis Test
- Systematic review
- Descriptive qualitative
- Descriptive quantitative (e.g. survey)
- Proposal and prototype development [exclude]

Clear Response

- 3. Ambulatory or In-patient
 - Ambulatory
 - In-patient
 - N/A
 - **Clear Response**
- 4. Which settings were involved in the study?
 - Outside the US
 - HIT leader (see below for list from Buntin, 2011)
 - Safety net provider
 - Rural provider
 - Other provider (not HIT leader, safety net or rural)
 - Pharmacist
 - Not mentioned
 - Clear Response

HIT Leader:

1 of 2

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Department of Defense Intermountain Healthcare in Salt Lake City, Utah; Partners Healthcare in Boston, Massachusetts; Regenstrief Institute in Indianapolis, Indiana; Vanderbilt in Nashville, Tennessee. Veterans Affairs system Kaiser Permanente health system National Health Service in the United Kingdom,

5. Comment

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Full Text Screening Form

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Review	Datarama	Reports	References	Forms	Manage Levels	Users	Project	
Logout								

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Health Information Technologies Classification Form

1. Is this article within the scope of the project?

```
Yes No
```

2. What is the article's purpose? [Circle One]

Descriptive

Qualitative [stop] Quantitative Other descriptive Clear Response

Hypothesis testing:

With Intervention, with concurrent comparison group:

Controlled Trial Cntrl. Before/After Clear Response

With intervention, without concurrent comparison group:

Pre-Post Time Series Historical control Clear Response

No intervention

Cross-sectional Case study with concurrent control Clear Response

Other hypothesis testing:

Case control Cohort Other Clear Response

Predictive analysis

Cost-effect Cost-benefit Other pred. analysis Clear Response

Review

- Systematic/MA Clear Response
- 3. Which Meaningful Use Core Objective(s) the HIT address
 - Demographics
 - Vital Signs
 - Problem Lists
 - Medication Lists
 - Allergy Lists
 - CPOE
 - Electronic Prescribing

1 of 3

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- Health Information Exchange
- Clinical Decision Support
- Data Privacy
- Clinical Quality Measures
- Drug Formulary Checks
- Clinical Lab Test Results
- Patient Lists by Condition
- Patient Specific Education
- Medication Reconcilliation
- Summary Care Records
- Electronic Immunization Registries
- Patient Care Reminders
- Patient Access to Electronic Records

4. What are the one or two main HIT elements being tested?

- Computerized Provider Order Entry
- Electronic Health Record
- Decision Support
- Results Reporting/Viewing Systems
- Electronic Prescribing
- Barcoding
- Mobile Computing
- Electronic Medication Admin. Record
- Information Exchange
- HIT in general
- Personal Health Record/Patient Portal
- Other (specify)

5. What are the types of healthcare organization settings?

- Hospital/inpatient
- Outpatient/ambulatory
- Integrated delivery Network (IDN)
- Emergency room
- Nursing home
- Patient home
- Pediatrics
- Pharmacy
- Internet
- Other setting (specify)
- N/A, N/R

6. Does this article report data from any of the following systems?

- Intermountain
- Partners
- Regenstrief
- 🗖 VA
- UK's NHS
- Kaiser
- Vanderbilt University
- Other (specify)

2 of 3

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N/A, N/R

7. Which outcomes are measured (numerically reported) in the article?

- Impact on patient safety
- Impact on patient satisfaction
- Impact on health care effectiveness and quality
- Impact on efficiency, utilization, and costs
- Impact on healthcare access
- Impact on healthcare disparities
- Other (specify)
- N/A, N/R

8. What years did the research take place?

(Enter 4-digit years. N/A, N/R: enter 9999)

Year began

Year ended

9. What types of health care conditions are being assessed?

- Cancer
- COPD
- Dementia
- Osteoarthritis
- Osteoporosis
- Depression
- Diabetes
- Heart Failure
- Hypertension
- Ischemic Heart Disease
- Stroke
- Atrial Fibrillation
- Screening and Prevention
- Other (specify)
- Other (specify)
- Not specified

10. Type of HIT

- Commercial HIT
- Commercial HIT product modified for intervention
- Homegrown HIT product
- Unspecified

11. Comments

Submit Form and go to or Skip to Next

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AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Quinn, et al. 2011 ⁷⁷	Controlled Trial, N=26 practices enrolled, N=163 patients in analyses	Outpatient/ Ambulatory	non-leader, Commercial health IT	Patient Specific Education	quality- outcomes	1.2% reduction in A1c levels	positive
Lavinge, et al. 2011 ⁷⁶	Controlled Trial, Total N=270; 208 boys (77.0%) and 62 girls (23.0%) (mean age: 8.2 years)	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	increased adherence to protocol and led to greater ADHD symptom reduction	mixed- positive
Neafsey, et al. 2011 ¹²	Controlled Trial, N=11 primary care practices; N=160 patient participants	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Patient Specific Education	quality- outcomes	significant increases in patients' improved behavior regarding medication adherence	Positive
O'Connor, et al. 2011 ⁶	Controlled Trial, N=11 clinics, N=40 primary care physicians N=2,556 patients	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	quality- outcomes	Significantly improved hemoglobin A1c. 5.1% more patients in the intervention group had controlled systolic blood pressure. However, no significant improvements in low-density lipoprotein cholesterol and diastolic blood pressure control.	mixed- positive
Holt, et al. 2010 ²⁸	Controlled Trial, Baseline population (N=19 practices) Intervention N=18,912; Controls N=19,235; Overall N=38,147 Outcome population(N=18 practices) Intervention N=18,021; Controls N=18,071; Overall N=36,092; Estimated mid-trial population (N=19 practices) Intervention N=19,191; Controls N=19,413; Overall N=38,604	Outpatient/ Ambulatory	UK's NHS, Commercial health IT	Patient Lists By Condition	quality- outcomes	Increased number of patients with complete documentation of cardiovascular risk factors (2.97% vs.1.06%).	Neutral

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Williams, et al. 2010 ⁷⁵	Cohort, N=4,198 patients	Outpatient/ Ambulatory	VA, Homegrown health IT Product	Patient Lists By Condition	quality- outcomes	Passive CDS alerts were associated with 3% higher rate of resolution of unhealthy alcohol use.	Positive
Holbrook, et al. 2011 ¹⁹	Controlled Trial, N=1,102 patients in N=49 community-based physician practices	Outpatient/A mbulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	Despite significantly higher rates of process quality improvement, a vascular risk CDS system was not associated with vascular outcomes.	Neutral
Virga, et al. 2012 ⁶⁴	Pre-Post, N=3 clinics, N=263 patients	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Health Information Exchange	quality- outcomes	HIV/AIDS focused health information exchange was associated with significant improvements in both patient outcomes studied.	positive
Tang, et al. 2012 ⁷⁸	Controlled Trial, N=415 randomized, N= 379 analyzed	Outpatient/A mbulatory	non-leader, Commercial health IT	Patient Care Reminders	quality- outcomes	Patients that received access to a multifaceted PHR platform achieved greater decreases in A1C at 6 months than control patients, but the differences were not sustained at 12 months. However, more intervention patients achieved improvement in A1C (>0.5% decrease in A1C).	positive
Herrin, et al. 2012 ⁶⁷	Pre-Post, N=34 primary care practices, N=14,051 diabetes patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	Among patients exposed to EHR, all process and outcome measures except HbA1c and lipid control showed significant improvement.	mixed positive
Gustafson, et al. 2012 ⁷⁹	Controlled Trial, N=301 parent-child dyads	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Patient Care Reminders	quality- outcomes	A web-based e-Health intervention with telephone nurse case management was associated with significantly better asthma control, but not more days of symptom control, or adherence to asthma controller, or self-efficacy, or information competence.	mixed positive
Wagner, et al. 2012 ¹⁴	Controlled Trial, N=453 patients in 2 ambulatory clinics.	Outpatient/A mbulatory	non-leader, Commercial health IT	Patient Access to Electronic Records	quality- outcomes	Active PHR use was associated with a 5.25 point reduction in diastolic BP; however, only 25% of users actively used the PHR.	mixed positive
Tenforde, et al. 2012^{66}	Descriptive Quantitative, N=10,746 adults with diabetes	Outpatient/A mbulatory	non-leader, Commercial health IT	Patient Access to Electronic Records	quality- outcomes	Use of a PHR was associated with increased likelihood of HbA1c testing (OR 2.06).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Shelley, et al. 2011^{23}	Pre-Post, N=4 clinics; N=2,697 patients pre; N=2,910 patients post	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	Implementation of a CDS intervention significantly improved blood pressure control in four community health centers (50.9% vs. 60.8%).	positive
Cebul, et al. 2011 ²¹⁴	Cross-sectional, N=27,207 adults with diabetes seen at 46 practices	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	A composite measure of diabetes related health outcomes was 15.2 percentage points higher in EHR sites. EHR was also associated with greater improvement in health outcomes (+ 4.1 percentage points in annual improvement)	positive
Kern, et al. 2013 ²¹⁵	Cross-sectional, N=466 physicians; N=74,618 unique patients.	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	Electronic health record use was associated with significantly higher quality of care for four of the measures: hemoglobin A1c testing in diabetes, breast cancer screening, chlamydia screening, and colorectal cancer screening. Effect sizes ranged from 3 to 13 percentage points per measure. When all nine measures were combined into a composite, EHR use was associated	positive
Deily, et al. 2013 ²¹⁶	Cross-sectional, N=491,832 births in Pennsylvania during 1998-2004	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- outcomes	Clinical HIT applications at NHFs may reduce the likelihood of adverse birth outcomes, particularly after physicians and staff gain experience using the technologies.	positive
Epstein, et al. 2011 ⁶⁸	Controlled Trial, N=8 practices, N=49 pediatricians, N=746 patient charts included	Outpatient/ Ambulatory	non-leader, Unspecified	Patient Care Reminders	quality- process	significantly improved quality of ADHD care in community-based pediatric settings	positive
Loo, et al. 2011 ⁵⁴	Controlled Trial, N=54 Physicians, N=4,660 Patients aged >65 y	Outpatient/ Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	2-12.8% improvement in screening and vaccination rates	positive
Carroll, et al. 2011 ²⁹	Controlled Trial, N=2,239 patients	Outpatient/ Ambulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	14.1% higher documentation rates for iron-deficient anemia risk factors and 1% higher for tuberculosis risk factors	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Chaudhry, et al. 2011 ⁴⁷	Pre-Post, N=883 patients from 1 January to 31 March 2007 and 880 patients for the same period in 2008	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Rate of abdominal aortic aneurism screening increased 12.6%	positive
Romano & Stafford, 2011 ⁷²	Cross-sectional, N=255,402ambulatory patient visits	Outpatient/ Ambulatory	non-leader, unspecified	Multifaceted health IT Intervention	quality- process	No consistent relationship between EHRs, CDS and better process quality	neutral
Gill, et al. 2011 ⁴⁰	Controlled Trial, N=27 offices, N=119 clinicians N=5,234 high-risk patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	e-Prescribing	quality- process	3% improvement in guideline adherence for non- steroidal anti-inflammatory drugs; however authors concluded that this finding was not likely to be clinically meaningful	mixed- positive
Jain, et al. 2011 ⁴⁶	Pre-Post, N=979 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Increased the rate of AATD screening by 10.4%; however the increased testing did not produce a significant increase in the AATD detection rate	positive
Persell, et al. 2011 ⁶³	Time Series, N=12,288 patients eligible for any measure	Outpatient/ Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	Nine measures of process quality improved significantly (3.2-18.1%)	positive
Sequist, et al. 2011 ⁵⁶	Controlled Trial, N=14 ambulatory health centers, N=109 primary care Physicians, N=1,103 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Patient Care Reminders	quality- process	Increased osteoporosis and colorectal screening 7.4%	positive
Atlas, et al. 2011 ⁵⁵	Controlled Trial, N=12 practice clusters, N=6,730 patients	Outpatient/ Ambulatory	Partners, Homegrown health IT Product	Patient Lists By Condition	quality- process	8.1% higher mammogram screening rates.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Player, et al. 2010 ¹⁷	Controlled Trial, Providers: N=53 Intervention N=66 Control; Patients: N=30,448 Intervention N=37,095 Control	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Odds of GERD diagnosis increased by 33% and the odds of diagnosis and treatment of GERD among the subset of patients with atypical symptoms increased by 102% and 40% respectively	positive
Williams, et al. 2010^{37}	Cohort, N=22,863 eligible patients included 10,392 controls and 12,471 intervention group	Outpatient/ Ambulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	no association with an increased rate of alcohol counseling or significant resolution of unhealthy drinking	neutral
Bourgeois,et al. 2010 ³⁶	Controlled Trial, N=12 pediatric practices N=12,316 patients <18 years of age	Outpatient/ Ambulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	CDS was not associated with improvement in adherence to clinical guidelines	mixed- positive
Dejesus, et al. 2010 ⁴⁵	Pre-Post, 2007 (before clinical decision support tool implementation) N=7,263 2008 (after clinical decision support tool implementation) N=7,411	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Improved osteoporosis screening rates by 4%	positive
Co, et al. 2010 ¹⁶	Controlled Trial, General Pediatricians N=79 Pediatric Primary Care Practices N=12 using same EHR and who were caring for N=412 children who were aged 5 to 18 years and	Outpatient/ Ambulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	17% higher ADHD guideline adherence	positive
Davis, et al. 2010 ²¹	Pre-Post, Pre Intervention Phase N=180 Post Intervention Phase N=180	Outpatient/ Ambulatory	non-leader, Commercial health IT	Patient Lists By Condition	quality- process	documentation of asthma severity increased by 20% and the use of inhaled corticosteroids increased more than 34%	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Walker, et al. 2010 ⁵³	Controlled Trial, Total N=68 clinics Control N=34 clinics (111GPs) Intervention N=34 (114 GPs)	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	quality- process	27% greater chlamydia screening rates than in the control group	mixed- positive
Holt, et al. 2010 ²⁸	Controlled Trial, Controlled Trial, Baseline population (N=19 practices) Intervention N=18,912; Controls N=19,235; Overall N=38,147 Outcome population(N=18 practices) Intervention N=18,021; Controls N=18,071; Overall N=36,092; Estimated mid-trial population (N=19 practices) Intervention N=19,191; Controls N=19,413; Overall N=38,604	Outpatient/ Ambulatory	UK's NHS, Commercial health IT	Patient Lists By Condition	quality- process	no reduction in the rate of cardiovascular events	positive
Bell, et al. 2010 ¹⁸	Controlled Trial, N=19,450 children with asthma	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Use of controller medications, spirometry, and up- to-date care plans were 6%, 3%, and 14% higher respectively in the intervention practices than in the control practices.	positive
Singh, et al. 2010 ³⁸	Cohort, N=1,163 eligible alerts	Outpatient/ Ambulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	Safety risks remained even in highly computerized environment.	negative
Kesman, et al. 2010 ⁵⁷	Cntrl. Before/After , N=689 eligible patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Patient Lists By Condition	quality- process	Patient reminders significantly increased osteoporosis screening 7.4%.	positive
Damberg, et al. 2010 ⁷³	Cross-sectional, N=108 California Physician Organizations	Outpatient/ Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	No correlation between EHR capabilities and composite quality measures for diabetes management, processes of care, and intermediate outcomes	neutral

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Feldstein, et al. 2010 ⁶⁵	Pre-Post, A mean of 20,705 (SD = 1,369; range 18,401-22,574) patients per month across all PCPs and a mean of 123 SD = 55;range 22-285) patients per month per PCP qualified for the DM analysis. A mean of 17,840 (SD = 1464; range = 15,168-19,473) patients per month across all PCPs and a mean of 124 (SD = 61; range 23-302) patients per month per PCP qualified for the CVD analysis. A total of 30,473 unique DM patients and 26,414 CVD patients were included in the monthly calculations across the 3 time periods (8543 were in both analyses).	Outpatient/ Ambulatory	Kaiser, Commercial health IT	Patient Lists By Condition	quality- process	Significantly increased compliance to guidelines for diabetes and cardiovascular disease (14.3% relative improvement for diabetes 10.6% relative improvement for cardiovascular disease)	positive
Samal, et al. 2011 ²⁴	Cross-sectional, N=20,924 Adult primary care visits	Outpatient/A mbulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	Rates of blood pressure control were significantly higher in visits where both an EHR and CDS (79%) were used compared with visits where physicians used neither tool (74%).	positive
Riley, et al. 2011 ²⁶	Time Series, Pre intervention N=144 patients, intervention N=115 patients, N=169 post intervention patients	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	quality- process	CDS alerts were associated with a 46.2% absolute increase in the number of prenatal patients that received all guideline recommended care. The percentage of patients receiving recommended care dropped 38.6% after the CDS alerts were deactivated.	positive
Holbrook, et al. 2011 ¹⁹	Controlled Trial, N=1,102 patients in N=49 community-based physician practices	Outpatient/A mbulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	A vascular risk CDS system was associated with significantly higher rates of improvement of a composite measure of process quality (an average difference of 4.70 on a 27-point scale over controls).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Laxmisan, et al. 2012 ²²	Pre-Post, N=1,637 patient charts	Outpatient/A mbulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	An EHR-based notification of pathology results improved the proportion of patients who received follow-up at 6 months (OR .7 pre-intervention vs. post-intervention).	positive
Carroll, et al. 2012 ³⁴	Controlled Trial, N=3,520 patients	Outpatient/A mbulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	A CDS alert for depression screening among new mothers was associated with significantly higher documentation rates for signs of depression and referral rates for depression assistance (2.4% vs. 1.2%).	positive
Coleman, et al. 2012^{30}	Time Series, N=739,816 children and adolescents per study year	Outpatient/A mbulatory	Kaiser, Commercial health IT	Clinical Decision Support	quality- process	CDS alerts were associated with absolute increases of 28% in the documentation of height and weight, 49% in the appropriate diagnosis of overweight or obesity, and a 49% increase in documented counseling rates among pediatric patients.	positive
Tang, et al. 2012 ⁷	Controlled Trial, N=30 Physicians, N=2,114 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Physicians given access to a passive CDS alert and documentation template were 12% more likely to provide weight specific counseling and 15% more likely do document that patients were overweight.	mixed positive
Chung, et al. 2012 ⁴¹	Time Series, Approximately N=6,000 patient charts per month for 2 years	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Implementation of a CDS alert to increase appropriate implantable device use in heart failure patients was not associated with significant increases in the adherence to practice guidelines.	neutral
Lapham, et al. 2012 ³³	Time Series, N=6,788 patients	Outpatient/A mbulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	Documentation of brief alcohol interventions among veterans with a history of alcohol misuse increased from 5.5% to 29% after the implantation of a CDS reminder.	positive
Eaton, et al. 2012 ³⁹	Descriptive Quantitative, N=442 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Despite the presence of guideline-based CDS alerts, less than 13% of eligible patients received screening for abdominal aortic aneurysm.	neutral
Abdel-Kader, et al. 2011 ⁴²	Controlled Trial, N=30 PCPs, N=248 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Non-interruptive CDS alerts we not associated with increased nephrologist referral or urine albumin quantification among patients with mild to moderate chronic kidney disease.	neutral

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Sequist, et al. 2012 ⁴³	Controlled Trial, N=292 Clinicians, N=7,083 adult patients	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	CDS alerts did not significantly increase risk- appropriate care for high or low risk patients with chest pain in primary care setting.	neutral
Mathias, et al. 2012^{44}	Cohort, pre N=1,349 smokers; post N=1,346 smokers	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	This provider-directed electronic alert and linked order set failed to increase cessation medication prescription.	neutral
Wright, et al. 2012 ³²	Controlled Trial, N=28 primary care practices, N=14 intervention and N=14 controls.	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	Providers exposed to CDS alerts were significantly more likely to document problems on the problem list (adjusted OR=3.4) than controls.	positive
Gill, et al. 2012 ⁸	Cohort, N=19 primary care practices, N=119 providers.	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	An EHR-based CDS tool for management of depression in primary care was associated with increased use of standardized tools for depression diagnosis (80 vs. 47%) and monitoring (85 vs. 27%).	positive
Mainous, et al. 2012 ²⁰	Controlled Trial, N=9 intervention practices, N=61 control practices	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	A CDSS embedded in an EHR had a modest effect in changing prescribing adults inappropriate antibiotics (-0.6%) and had a substantial impact on changing the overall prescribing of broad-spectrum antibiotics among pediatric (-19.7%) and adult patients (-16.6%).	positive
Roshanov, et al. 2012 ³⁵	Pre-Post, N=31 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	A computerized system for evidence-based diabetes care was associated with a significant decrease in documentation incompleteness (10.1% post implementation vs. 26.3% pre implementation).	positive
Koplan, et al. 2012 ²⁵	Pre-Post, N=1 large multi-specialty practice	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	CDS alerts to improve Warfarin monitoring when initiating interacting medications were associated with a 5% absolute improvement in the rate of anticoagulation monitoring (39% vs. 34%).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Campbell, et al. 2012 ²⁷	Descriptive Quantitative, N=1,682 GI endoscopy procedures	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	Clinicians accepted 4.2% of alerts from an automated before-procedure EHR-based CDS system to ensure appropriateness for GI endoscopy and sedation. The authors concluded that use of the CDS system might improve provider efficiency and patient outcomes in endoscopy units. However, the low rate of acceptance suggests that alert fatigue may be a barrier.	mixed positive
Keehbauch, et al. 2012 ³¹	Cntrl. Before/After, N=2 community based family clinics	Outpatient/A mbulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	An EHR based automated BMI calculator was associated with significant increase in obesity documentation and counseling rates. The same study found that documentation and counseling rates were even higher for clinicians that also received education.	positive
Shelley, et al. 2011 ²³	Pre-Post, N=4 clinics; N=2,697 patients pre; N=2,910 patients post	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Implementation of a CDS intervention significantly improved adherence to a number of hypertension best practices in four community health centers including BMET or CMET (79.1 vs. 92.2%), ECG (6.6% vs. 52.2%), lipid panel (69.1 vs. 78.7%), BMI (71.6 vs. 84.5%)	positive
Williams, et al. 2011 ⁴⁸	Cntrl. Before/After, N=278 intervention patients; N=374 control patients	Outpatient/A mbulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	A CDS alert to for post-stroke depression (PSD) was associated with a 4.8 times increase in the odds of PSD screening and a 2.5 times increase in the odds of treatment action among those that screened positive.	positive
Bian, et al. 2012 ⁶²	Time Series, N=4,352,082 patient-years	Outpatient/A mbulatory	VA, Homegrown health IT Product	Clinical Decision Support	quality- process	The CDS intervention to increase screening among high risk patients was associated with a 2.2% decrease in likelihood of adherence to colorectal cancer screening guidelines among the recommended patient population. The authors hypothesized that the counter-intuitive result might be due a shift of limited VA colonoscopy capacity from average-risk screening to higher-risk screening, or due to alert fatigue.	negative

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Tundia, et al. 2012 ⁴⁹	Cross-sectional, N=726,625 Physician Office visits among women age 21 and older	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	A minimal EHR was positively associated with 5 of 11 measures of women's preventive healthcare. Results also suggest more sophisticated EHRs are associated with higher number of women's preventive healthcare tests and exams.	mixed positive
Hsu, et al. 2012 ⁵⁰	Controlled Trial, N=76 PCPs, N=175 outpatient adults	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	EHR-based CDS alerts significantly increased (40.9 vs. 1.1%) HBV testing in Chinese and Vietnamese patients when compared to "usual care.	positive
Krist, et al. 2012 ⁶⁰	Controlled Trial, N=4,500 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Patient Care Reminders	quality- process	After 16 months of use patients that adopted a PHR were nearly twice as likely to be up to date on recommended preventative services as patients in the control group (25.1 vs. 12.6%). However, less than 17% of the patients in the intervention group used the PHR.	mixed positive
Dombkowski, et al. 2012 ⁶¹	Controlled Trial, N=3,618 patients	Outpatient/A mbulatory	non-leader, Unspecified	Electronic Immunization Registries	quality- process	Among patients in a state immunization information system (IIS), reminders were positively associated with seasonal influenza vaccination. However, more than 40% of children assigned to receive a reminder were determined to have an invalid or undeliverable address, emphasizing the need for increased quality of IIS contact information.	mixed positive
Lau, et al. 2012 ⁵⁸	Controlled Trial, N=742 patients	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Patient Care Reminders	quality- process	Patients with access to the PHR were 6.7% more likely to receive influenza vaccination.	positive
Klatt, et al. 2012^{51}	Pre-Post, N=640 female patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	A CDS alert was associated with a 19% increase in vaccination rate (61% vs. 42%) among obstetric patients.	positive
Gill, et al. 2012 ⁵²	Controlled Trial, Intervention: N=21 practices, N=75 clinicians, N=8,355 adult patients with depression Control: N=17 practices, N=81 clinicians, N=8,799 adult patients with depression	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	An EHR based screening tool for bipolar disorder was associated with increased detection of bipolar disorder (1.1 vs36%) and prescription of appropriate medications (1.85 vs. 1.19%).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Wright, et al. 2012 ⁵⁹	Controlled Trial, N=3,979 patients	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Patient Care Reminders	quality- process	Health maintenance reminders provided directly to patients through the PHR intervention were associated with increased mammography rates (48.6% vs. 29.5%) and influenza vaccinations (22.0% vs. 14.0%). No significant differences were detected in rates of bone density testing, cholesterol testing, Pap smear and pneumococcal vaccination.	mixed positive
Crosson, et al. 2012^{69}	Controlled Trial, N=42 primary care practices	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	EHR use was not associated with better adherence to care guidelines or a more rapid improvement in adherence to guidelines.	neutral
Herrin, et al. 2012 ⁶⁷	Pre-Post, N=34 primary care practices, N=14,051 diabetes patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	Among patients exposed to EHR, all process and outcome measures except HbA1c and lipid control showed significant improvement.	positive
Hacker, et al. 2012 ⁷¹	Time Series, N=7 pediatricians	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	One month after EHR implementation behavioral health screening rates dropped from 83 to 55%, and screening rates did not return to baseline levels until three years post implementation.	negative
Walsh, et al. 2012 ⁷⁰	Cross-sectional, N=155 ambulatory practices	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Implementation of the performance improvement intervention increased adherence to heart failure guidelines in outpatient cardiology practices. However, practices using or converting to an EHR did not achieve greater improvements in quality of heart failure care than practices using paper systems.	neutral
Virga, et al. 2012 ⁶⁴	Pre-Post, N=3 clinics, N=263 patients	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Health Information Exchange	quality- process	HIV/AIDS focused health information exchange was associated with significant increases in syphilis screening (67 to 87%) but was not associated with three other indicators of process quality.	mixed positive
Harman, et al. 2012 ⁷⁴	Cross-sectional, N=3,467 ambulatory visits	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	The presence of EHR was associated with significantly lowered odds (OR=0.5) that patients with three or more comorbid conditions received depression treatment.	negative
Tenforde, et al. 2012^{66}	Descriptive Quantitative, N=10,746 adults with diabetes	Outpatient/A mbulatory	non-leader, Commercial health IT	Patient Access to Electronic Records	quality- process	Use of a PHR was associated with significantly lower HbA1c (-0.29%).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Nagykaldi, et al. 2012 ¹³	Controlled Trial, N=8 clinical practices	Outpatient/A mbulatory	non-leader, Homegrown health IT Product	Patient Access to Electronic Records	quality- process	Access to a patient portal was associated with increased adherence to recommended preventive care services (84.4 vs. 67.6%).	positive
Cebul, et al. 2011 ²¹⁴	Cross-sectional, N= 27,207 adults with diabetes seen at 46 practices	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	Compliance with standards for diabetes care was 35.1 percentage points higher at EHR sites than at paper-based sites. EHR was also associated with greater improvement in process quality and (+10.2 percentage points in annual improvement)	positive
Ryan, et al. 2013 ²¹⁷	Cntrl. Before/After, N=360 physicians and 360 matched comparison physicians	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	EHRs with help for implementation improved scores on the following measures after 9 months: breast cancer screening for women, retinal exam for patients with diabetes, urine testing for patients with diabetes, chlamydia screening for women, and colorectal cancer screening.	mixed positive
McCullough, et al. 2013 ²¹⁸	Cross-sectional, N=557 clinics	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Different in different approach.	mixed- positive
Litvin, et al. 2013 ²¹⁹	Time Series, CDSS was used 38,592 times during the 27-month intervention	Outpatient/A mbulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- process	Use of antibiotics for encounters at which diagnoses for which antibiotics are rarely appropriate did not significantly change through the course of the study (estimated 27-month change, 1.57% [95% CI, - 5.35%, 8.49%] in adults and -1.89% [95% CI, - 9.03%, 5.26%] in children). However, use of broad spectrum antibiotics for ARI encounters improved significantly (estimated 27 month change, -16.30%, [95% CI, -24.81%, -7.79%] in adults and -16.30 [95% CI, -23.29%, -9.31%] in children). Prescribing for bronchitis did not change significantly, but use of broad spectrum antibiotics for sinusitis declined.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Frimpong, et al. 2013 ²²⁰	Cross-sectional, N=776 federally qualified health centers	Outpatient/A mbulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	FQHCs with higher HIT capacity were significantly more likely to have improved quality of care, measured by the receipt of discharge summaries (OR=1.43; CI=1.01, 2.40), the use of a patient notification system for preventive and follow-up care (OR=1.74; CI=1.23, 2.45), and timely appointment for specialty care (OR=1.77; CI=1.24, 2.53).	positive
Duke, et al. 2013 ²²¹	Controlled Trial, N=671 residents and 358 staff physicians	Outpatient/A mbulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	No significant difference in alert adherence in high- risk patients between the intervention group (15.3%) and the control group (16.8%) (p=0.71). Adherence in normal risk patients was significantly lower in the intervention group (14.6%) than in the control group (18.6%) (p<0.01). In neither group did physicians increase adherence in patients at high risk.	neutral
Baer, et al. 2013 ²²²	Controlled Trial, N=15,495	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Problem Lists	quality- process	Among eligible intervention patients, 2.0% had new information on family history of cancer entered in the EHR within 30 days after the visit, compared to 0.6% of eligible control patients (adjusted odds ratio = 4.3 , p = 0.03). There were no significant differences in the percent of patients who received moderate or high risk reminders for colon or breast cancer screening.	mixed- positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Robbins, et al. 2013 ²²³	Controlled Trial, N=1,011 patients with HIV	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	Thirty-three HIV care providers followed 1011 patients with HIV. In the intervention group, the mean increase in CD4 cell count was greater (0.0053 vs. 0.0032 x 109 cells/L per month; difference, 0.0021 x 109 cells/L per month [95% CI, 0.0001 to 0.004]; P = 0.040) and the rate of 6- month suboptimal follow-up was lower (20.6 vs. 30.1 events per 100 patient-years; P = 0.022) than those in the control group. Median time to next scheduled appointment was shorter in the intervention group than in the control group after a suboptimal follow-up alert (1.71 vs. 3.48 months; P < 0.001) and after a toxicity alert (2.79 vs. >6 months; P = 0.072). More than 90% of providers supported adopting the CDSS as part of standard care.	positive
Kern, et al. 2013 ²¹⁵	Cross-sectional, N=466 physicians; N=74,618 unique patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	Electronic health record use was associated with significantly higher quality of care for four of the measures: hemoglobin A1c testing in diabetes, breast cancer screening, chlamydia screening, and colorectal cancer screening. Effect sizes ranged from 3 to 13 percentage points per measure. When all nine measures were combined into a composite, EHR use was associated	positive
El-Kareh, et al. 2012 ²²⁴	Cross-sectional, N=157 alerts, 121 physicians	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	Alerting system improved the proportion of important post-discharge microbiology results with documented follow-up, though the proportion remained low. The alerts were well received and may be expanded in the future.	mixed- positive
Neafsey, et al. 2011 ¹²	Controlled Trial, N=160 patients Control N=73 Intervention N=87	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Patient Specific Education	quality- satisfaction	significant increases in patients' knowledge of self- medication practices for hypertension	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
O'Connor, et al. 2011^6	Controlled Trial, N=11 clinics, N=40 primary care physicians N=2,556 patients	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	quality- satisfaction	94% rate of user satisfaction	positive
Duffy, et al. 2010 ¹¹	Pre-Post, Calls/1,000 Office Visits (n=number of calls) Before ERx Call N=1,101 Immediately after ERx call N=944 One year after ERx call N=990 Total N=3,035	Outpatient/ Ambulatory	non-leader, Commercial health IT	e-Prescribing	quality- satisfaction	22% decrease in after-hours calls to an academic- affiliated ambulatory clinic.	positive
Zandieh, et al. 2012 ¹⁰	Pre-Post, N=523 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- satisfaction	Overall, the majority of providers were satisfied with both their old and new EHRs. However, when asked about specific functionalities providers were more satisfied with the remote access and referral communication functionalities of the new EHRs (40 vs. 74% and 51 vs. 69%). However, providers were neutral or less satisfied with 11 other functionalities of the newer EHRs.	mixed positive
Tang, et al. 2012 ⁷	Controlled Trial, N=30 Physicians, N=2,114 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- satisfaction	82% of physicians given access to a passive CDS alerts and documentation templates reported that the CDS system improved the effectiveness of their counseling. However, many physicians sited time as a major barrier to using the CDS system.	mixed positive
Gill, et al. 2012 ⁸	Cohort, N=19 primary care practices with N=119 providers	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- satisfaction	85% of clinicians planned to continue to use an EHR-based CDS tool for management of depression in primary care after conclusion of the study.	positive
Bell, et al. 2012 ¹⁵	Controlled Trial, N=171 laboratory alerts	Outpatient/ Ambulatory	non-leader, Commercial health IT	Health Information Exchange	quality- satisfaction	Patients rated communication about laboratory tests more highly after the implementation of the HIE (91 vs. 83 on a 100-point scale); ratings were not higher for other aspects of care.	mixed positive
Heselmans, et al. 2012 ⁹	Descriptive Quantitative, N=39 family physicians	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- satisfaction	66% of family physicians had positive perception of a CDS system during the first year of implementation.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Wagner, et al. 2012^{14}	Controlled Trial, N=453 patients in N=2 ambulatory clinics.	Outpatient/ Ambulatory	non-leader, Commercial health IT	Patient Access to Electronic Records	quality- satisfaction	Use of a PHR was not associated with significant change in patient satisfaction and only 25% of PHR users frequently accessed their PHR.	neutral
Nagykaldi, et al. 2012 ¹³	Controlled Trial, N=8 clinical practices	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Patient Access to Electronic Records	quality- satisfaction	83% of patients reported that they found wellness patient portal valuable.	positive
Delbanco, et al. 2012 ²²⁵	Cohort, N=105 PCPs and 13,564 of their patients	Outpatient/ Ambulatory	non-leader, Unspecified	Patient Access to Electronic Records	quality- satisfaction	Patients accessed visit notes frequently, a large majority reported clinically relevant benefits and minimal concerns, and virtually all patients wanted the practice to continue.	positive
Feblowitz, et al. 2013 ²²⁶	Descriptive Quantitative, N=140 providers (130 MDs, 6 NPs, and 4 PAs)	Outpatient/ Ambulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- satisfaction	Alert acceptance rate was 38.1%, individual provider acceptance rates varied widely, with an interquartile range (IQR) of 14.8%-54.4%, and many outliers accepting none or nearly all of the alerts they received. No demographic variables, including degree, gender, age, assigned clinic, medical school or graduation year predicted acceptance rates	neutral

Evidence Table 2: health IT and Quality of Care in Non-ambulatory Settings

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Jones, et al. 2011 ¹²²	Cross-sectional, N=2,543 included hospitals N=2,101 excluded hospitals from the study of Electronic Medication Order Entry, 2007	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	quality- outcomes	2.1% reduction in mortality among heart attack and heart failure patients	mixed- positive
Cochran, et al. 2011^{130}	Pre-Post, N=21,202 pregnancies	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	14- 31% fewer maternal health visits to the regional tertiary medical center.	neutral
Lapane, et al. 2011 ¹³⁴	Controlled Trial, N=64 focus groups with a total of N=276 participants	Non- Ambulatory	non-leader, Commercial health IT	Medication Lists	quality- outcomes		mixed- positive
Pillemer, et al. 2011 ⁸³	Cntrl. Before/After , N=761 residents N=428 comparison group N=333 control group	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	No significant improvement on any standard nursing home outcome measures but some negative effects on behavioral outcome measures	negative
Mann, et al. 2011 ⁹²	Controlled Trial, N=22 enrolled patients N=18 completed study	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	6% better glucose control	positive
Moore, et al. 2010 ¹¹⁸	Cohort, N=87 patients	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	Mortality was significantly less than expected after the implementation of the CDS (24% observed mortality vs. 62.5% expected mortality).	positive
Refuerzo, et al. 2011 ¹²⁵	Pre-Post, N=154 pregnant women N=83 paper based order entry N=71 CPOE	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	quality- outcomes	Induction agent turnaround times in a single labor and delivery unit decreased 29%	neutral
Longhurst, et al. 2010^{121}	Pre-Post, N=80,063 Pre-EMR N=17,432 Post-EMR	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- outcomes	Adjusted mortality rate decreased by 20%	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Furukawa, et al. 2010 ¹²⁶	Time Series, N=326 short-term, general acute care hospitals in California N=2,828 hospital-year observations	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- outcomes	3-4% lower rates of in-hospital morality	mixed- positive
Hoekstra, et al. 2010 ¹¹⁹	Pre-Post, N=2,210 patients N=775 before implementation of GRIP-II N=1,435 after implementation of GRIP-II	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	Hypokalemia decreased 1.7% (from 2.4% to 1.7%) and hyperkalemia decreased 2.6% (from 7.4% to 4.8%)	positive
Guerra, et al. 2010^{123}	Pre-Post, N=438 diabetic patients N=241 Pre-CPOE-HIP N=197 Post-CPOE-HIP	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- outcomes	Significant decrease in excessively high glucose levels without increasing clinically meaningful hypoglycemic events	positive
Wiljer, et al. 2010 ¹²⁷	Pre-Post, N=316 participants N=248 registered N=68 non-registered	Non- Ambulatory	non-leader, Homegrown health IT Product	Patient Access to Electronic Records	quality- outcomes	No association with increased patient anxiety (a positive finding), no association with a significant change in self-efficacy (a neutral finding).	mixed- positive
Rantz, et al. 2010 ¹²⁹	Cntrl. Before/After, N=18 nursing facilities	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	significant improvements in residents' range of motion and risk for pressure sores	positive
Cook, et al. 2011 ¹¹⁵	Pre-Post, No of charts=2,181 Pre-EMR No of charts=3,456 Post-EMR	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- outcomes	18.7% decrease in nosocomial Clostridium difficile and a 45.2% decrease in MRSA infections	positive
Jones, et al. 2011 ¹²⁸	Cross-sectional, N-2,406 hospitals	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- outcomes	No association with lower hospital readmission rates; however, high levels of electronic documentation were associated with modest reductions in readmission for heart failure (24.6% vs. 24.1%) and pneumonia (18.4% vs. 17.9%).	mixed- positive
Lakshminarayan et al, 2012 ⁹⁹	Pre-Post, N=952 Stroke Admissions	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	An EHR-based CDS system for Dysphagia screening was not significantly associated with any improvement in patient outcomes, including hospital length of stay, in-hospital mortality, or pneumonia rates.	neutral

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Austrian, et al. 2011 ¹⁰⁰	Cntrl. Before/After, N=1,006 and N=1,081 patients in the control and intervention groups, respectively	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	A heparin-induced thrombocytopenia (health IT) CDS alert was associated with a 33% relative increase in health IT antibody test orders.	neutral
Schwann, et al. 2011^{101}	Pre-Post, N=19,744 surgical procedures	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	Point of care CDS was associated with a 0.4% absolute risk reduction in the incidence of surgical site infection.	positive
Haut, et al. 2012 ¹⁰⁷	Cohort, N=1599 hospitalized adult trauma patients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	CDS was associated with a statistically significant increase in compliance with guideline-appropriate prophylaxis, from 66.2% to 84.4%.	positive
Milani, et al. 2011 ¹⁰²	Controlled Trial, N=80 patients, N=47 control, N=33 intervention	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	A CDS alert targeting patients' severe chronic kidney disease and acute coronary syndrome was not associated with reduced incidence of in-hospital bleeding.	neutral
Kooij, et al. 2012 ¹²⁰	Pre-Post, N=981 patients control; N=1,681 patients intervention.	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- outcomes	Automated CDS reminders were associated with a significant reduction in postoperative nausea and vomiting incidence in a general surgical population (23 vs. 27%)	positive
Umscheid, et al. 2012^{106}	Time Series, N=223,062 inpatients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	A clinical decision support intervention to improve venous thromboembolism prophylaxis was associated with reduced VTE events (from 2.2 to 1.7%).	positive
Schenarts, et al. 2012 ¹³¹	Pre-Post, N=5,996 patients	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	EHR was associated with significantly decreased hospital length of stay; intensive care unit length of stay; ventilator days; complications including: acute respiratory distress syndrome, pneumonia; myocardial infarction; line infection; septicemia; renal failure; drug complications; and delay in diagnosis. There was no difference in mortality, unexpected cardiac arrest, missed injury, pulmonary embolism/deep vein thrombosis, or late urinary tract infection.	mixed positive
Connelly, et al. 2012^{133}	Cross-sectional, N=5,166 adults with heart failure in 3 metropolitan Emergency Departments	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	In two of the three EDs studied, the presence of a prior record in the EHR was associated with lower in-hospital mortality (OR=0.45 and 0.55) among heart failure patients.	mixed positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Dowding, et al. 2012 ¹³²	Time Series, N=29 hospitals	Non- Ambulatory	Kaiser, Commercial health IT	Multifaceted health IT Intervention	quality- outcomes	EHR implementation was associated with a 13% decrease in hospital acquired pressure ulcer rates but no decrease in fall rates.	mixed positive
Dumont, et al. 2012^{124}	Controlled Trial, N=300 ICU patients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- outcomes	A computerized insulin dose calculator was associated with significantly likelihood that ICU patient glucose measurements were in the target range than in the controls (70.4% vs. 61.6%).	positive
Milani, et al. 2012 ⁸⁹	Cross-sectional, N=1,321 patients	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	quality- outcomes	COMPUTERIZED PROVIDER ORDER ENTRY and CDS were associated with a 5.7 times increase in the odds that patients admitted for acute coronary syndrome received guideline recommended care.	positive
Mazars, et al. 2012 ⁸⁷	Cntrl. Before/After, N=122 patients	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	quality- outcomes	A neonatal pain management module in the COMPUTERIZED PROVIDER ORDER ENTRY system was not associated with a significant change in the duration of invasive ventilation, or hospital stay, or the number of nosocomial infections.	neutral
Speedie, et al. 2013 ²²⁷	Cross-sectional, N= 3 EDs (13 227 patients total)	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- outcomes	No impact on mortality; 7% fewer laboratory test orders at one ED and 3% fewer at another; fewer diagnostic procedures were performed at two of the sites. At one site 36% fewer medications were ordered. The odds of being hospitalized were lower for EHR patients at one site and hospital LOS was shorter at two of the sites. EHR patient ED LOS was 18% longer at one site.	mixed positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Cho, et al. 2013 ²²⁸	Pre-Post, N=348 patients	Non- Ambulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality outcomes	HAPU prevalence rate fell from 21% to 4.0% and the ICU length of stay shortened from 7.6 to 5.2 days. After adjustment for primary diagnoses and illness severity, the intervention group was significantly less likely than the baseline group to develop HAPU [odds ratio (OR)=0.1, p<0.0001] and had a shorter ICU length of stay (OR=0.67, p<0.0001). Data entry regarding ulcer severity and body site increased, and the participants used PU Manager more than once a day for over 80% of eligible cases. Attitudes toward PU Manager were positive.	positive
Dexheimer, et al. 2011 ⁹⁵	Pre-Post, ED patients >65 years N= 3371 N=3149 not vaccinated N=222 vaccinated	Non- Ambulatory	Vanderbilt University, Homegrown health IT Product	Clinical Decision Support	quality- process	6.6% increase in vaccination rates	positive
Wilbur, et al. 2011 ⁹⁶	Cohort, N= 5,794 eligible patients	Non- Ambulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	75.5% of patients targeted received HIV screening	positive
Downs, et al. 2010 ¹⁰⁸	Cohort, N=87,916 pediatric visits for over 40,000 patients	Non- Ambulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	Physicians responded to only 43.9% of alerts	negative
Haynes, et al 2011 ⁸⁸	Time Series, A) Intervention Hospital N=5,132 Surgeries Pre- Intervention N=5,189 Surgeries Post- Intervention B) Control Hospital N=3,850 Surgeries Pre- Intervention N=4,043 Surgeries Post- Intervention	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- process	16.9% increase in guideline adherence	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Westphal, et al. 2011 ⁹¹	Pre-Post, N=471 pneumonia patients N=104 before intervention N=367 after intervention	Non- Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	quality- process	Guideline adherence for antibiotic prescribing increased 18%	mixed- positive
Mann, et al. 201 ⁹²	Controlled Trial, N=22 enrolled patients N=18 completed study	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Nursing staff took more glucose measurements, and that compliance with clinical guidelines was higher in the intervention group than in the control group	positive
Galanter, et al. 2010^{105}	Pre-Post, N=38,647 adult Admissions N=18,317 Control Group N=20,330 Intervention Group	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	VTE prophylaxis increased 10.9% and the rate of VTE in medical units decreased significantly (0.55% to 0.33%)	positive
Overbeek, et al. 2010^{97}	Controlled Trial, N=266 patients N=156 Intervention N=110 Control	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	Patients at high risk for Lynch syndrome were recognized 77% of the time in the intervention group versus 59% in the control	positive
McCullough, et al. 2010 ¹¹⁰	Time Series, N=3,401 nonfederal, acute care U.S. hospitals	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Statistically significant improvements on two of six quality measures (pneumococcal vaccinations and appropriate antibiotic use)	mixed- positive
DesRoches, et al. 2010 ¹¹¹	Time Series, N=3,049 completed surveys	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	small, but statistically significant process quality gains	mixed- positive
Fiumara, et al. 2010 ¹⁰⁴	Cohort, N=880 patients N=425 patients received One- screen alert N=455 patients received Three- screen alert	Non- Ambulatory	Partners, Homegrown health IT Product	Clinical Decision Support	quality- process	Multi-screen CDS for VTE prophylaxis for high- risk patients was 7.6% more effective than a single screen CDS	positive
Poon, et al. 2010 ¹¹²	Cross-sectional, N=507 No. of Respondents	Non- Ambulatory	Partners, Unspecified	Multifaceted health IT Intervention	quality- process	No association between access to EHR and HEDIS measures, but did find some positive associations between EHR features and selected HEDIS measures	mixed- positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
McCluggage, et al. 2010 ⁹⁰	Pre-Post, N=522 vancomycin orders included N=279 Pre-implementation group N=243 post-implementation group	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- process	12% increase (from 24% to 36%) in vancomycin guideline adherence.	positive
Himmelstein, et al. 2010 ¹¹⁶	Time Series, N=20,269 hospitals incl in HIMSS Survey between 2003- 2007 N=16,991 hospitals incl in HIMSS Survey and Medicare Cost Report between 2003-2007	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Higher overall computerization scores correlated weakly with better quality score for acute myocardial infarction but not for heart failure or pneumonia.	mixed- positive
Carman, et al. 2011 ⁹³	Pre-Post, N=873 patient encounters	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Appropriate antibiotic coverage for patients with MRSA increased 9.9% (from 86.8% to 96.7%); however the rate of orders for wound cultures decreased by 31%, a result the authors interpreted as a negative finding	mixed- positive
Clemens, et al. 2011 ⁹⁴	Cohort, N=265 patients N=82 preferred Regimen N=183 Non-preferred Regimen	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- process	Guidelines were followed only 30.9%, a finding the authors interpreted as a negative result.	neutral
Cook, et al. 2011 ¹¹⁵	Pre-Post, No of charts=2,181 Pre-EMR No of charts=3,456 Post-EMR	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- process	28% decrease in antimicrobial utilization.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Jones, et al. 2010 ¹¹⁴	Cntrl. Before/After , N=2,021 All Hospitals N=1,535 No EHR N=445 Basic EHR N=41 Advanced EHR	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Basic EHR was associated with a significant 2.6% increase in quality improvement for heart failure. However, adoption of advanced EHR capabilities was associated with significant decreases in quality improvement for acute myocardial infarction (-0.9%) and heart failure (-3.0%) among hospitals that newly adopted an advanced EHR, and 1.2% less improvement for acute myocardial infarction quality scores and 2.8% less improvement for heart failure quality scores among hospitals that upgraded their basic EHR	mixed- positive
May, et al. 2012 ⁹⁸	Cohort, N=251 patients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	The use of CDS reminders was associated absolute increases in compliance to infection control precautions between 14 and 16%.	positive
Lakshminarayan et al. 2012 ⁹⁹	Pre-Post, N=952 Stroke Admissions	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	An EHR-based CDS system for Dysphagia screening was associate with significantly increased screening compliance (from 36% to 74%).	positive
Austrian, et al. 2011 ¹⁰⁰	Cntrl. Before/After, N=1006 and N=1081 patients in the control and intervention groups, respectively	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	A heparin-induced thrombocytopenia (HIT) CDS alert was not associated a significant difference in the HIT antibody-positive test rate, length of stay, and mortality in the intervention and control groups.	positive
Schwann, et al. 2011 ¹⁰¹	Pre-Post, N=19,744 surgical procedures	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	Point of care CDS was associated with 30% increase in compliance with surgical infection prevention guidelines.	positive
Haut, et al. 2012 ¹⁰⁷	Cohort, N=1,599 hospitalized adult trauma patients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	CDS was associated with a statistically significant decrease in the rate of preventable harm from VTE, from 1.0% to 0.17%.	positive
Milani, et al. 2011 ¹⁰²	Controlled Trial, N=81 patients, N=47 control, N=33 intervention	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	A CDS alert targeting patient's severe chronic kidney disease and acute coronary syndrome was associated with reduced incidence of patients being prescribed contraindicated medications.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Boustani, et al. 2012 ¹⁰⁹	Controlled Trial, N=225 intervention patients, N=199 control patients	Non- Ambulatory	Regenstrief, Homegrown health IT Product	Clinical Decision Support	quality- process	The CDS intervention was not associated with significant differences in any of the studied quality measures geriatric care (number of geriatric consult orders, discontinuation orders for Foley catheterization, use of physical restraints, or use of anticholinergic drugs).	neutral
Delmonte et al. 2012 ¹⁰³	Pre-Post, Pre-alert: N=171 patients; Post- alert: N=157 patients	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	quality- process	Implementation of a CDS alert in inpatient a psychiatric unit significantly improved rates of ordering fasting blood glucose and lipid levels for inpatients.	positive
Umscheid, et al. 2012 ¹⁰⁶	Time Series, N=223,062 inpatients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	quality- process	A clinical decision support intervention to improve venous thromboembolism prophylaxis was associated with increased use of recommended and prophylaxis (from 6.6 to 9.6%).	positive
Swenson, et al. 2012 ¹¹⁷	Pre-Post, Not Reported	Non- Ambulatory	non-leader, Unspecified	Patient Lists by Condition	quality- process	The intervention led to a 10% improvement in immunization rates in adults 65 years of age or older and in younger adults with diabetes or chronic obstructive pulmonary disease.	positive
Appari, et al. 2012 ¹¹³	Pre-Post, N=3,921 nonfederal acute-care U.S. hospitals	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- process	Hospitals transitioning to EHR systems capable of meeting 2011 Meaningful Use objectives saw incremental process quality improvements between 0.35-0.49%. However, hospitals that transitioned to more advanced systems saw incremental declines of 0.9-1%.	mixed positive
Mazars, et al. 2012 ⁸⁷	Cntrl. Before/After, N=122 patients	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	quality- process	A neonatal pain management module in the COMPUTERIZED PROVIDER ORDER ENTRY system was associated with a significant increase in the portion of patients that received a pain assessment (64 to 88%), documentation of pain scores also improved.	positive
Magid, et al. 2012 ²²⁹	Time Series, N=84 weeks	Non- Ambulatory	Kaiser, Commercial health IT	Clinical Decision Support	quality- process	After interventions, there was an 84.8% decrease in the duplication rate from weeks 1 to 84 and a 94.6% decrease from the highest (1) to the lowest week (75).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Pillemer, et al. 2011 ⁸³	Cntrl. Before/After , N=761 residents N=428 comparison group N=333 control group	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- satisfaction	No significant improvement on any standard nursing home outcome measures but some negative effects on behavioral outcome measures	negative
Nazi, et al. 2010 ⁸⁰	Descriptive Quantitative, N=100,617 My HealtheVet respondents	Non- Ambulatory	VA, Homegrown health IT Product	Patient Access to Electronic Records	quality- satisfaction	High user satisfaction (8.3 on a scale of 1 to 10), that users were likely to return to the site (8.6 on a scale of 1 to 10), and that users would recommend the system to other veterans (9.1 on a scale of 1 to 10)	positive
Do, et al. 2011 ⁸¹	Descriptive Quantitative, N=250 MiCARE enrolled users	Non- Ambulatory	non-leader, Commercial health IT	Patient Access to Electronic Records	quality- satisfaction	91.7 % of patients were satisfied the overall functionality of the personal health record.	positive
Bernstein, 2010 ⁸⁴	Cohort, 272-bed tertiary care women's and children's hospital N=60 residents	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	quality- satisfaction	3% of residents reported spending more than half of their documentation time on sign out notes, down from 30% at baseline	positive
Hoonakker, et al. 2012 ⁸⁵	Time Series, N=177 nurse and physician respondents at follow up point 1, and N=220 nurse and physician respondents at follow up point 2 (56% overall response rate).	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- satisfaction	ICU clinicians are moderately satisfied with COMPUTERIZED PROVIDER ORDER ENTRY, and satisfaction of ICU nurses, but not ICU physicians, with COMPUTERIZED PROVIDER ORDER ENTRY increased over time.	mixed positive
Kazley, et al. 2012 ⁸²	Cross-sectional, N=2,836 acute care general	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	quality- satisfaction	Electronic health record use was positively associated with significant increases in 3 of 10 measures of patient satisfaction.	mixed positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Holden, et al. 2012 ⁸⁶	Descriptive Quantitative, N=39 respondents	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	quality- satisfaction	24 % of percent of pharmacists reported that a BCMA system was "not at all" easy to use, 37% reported that BCMA did not improve their job performance, and 52% reported that they did not believe the BCMA system improved patient safety. Authors concluded that the primary reason for the poor perception of the BCMA was the lack of usability.	negative
Cho, et al. 2013 ²²⁸	Pre-Post, N=348 patients	Non- Ambulatory	partners, Homegrown health IT Product	Clinical Decision Support	quality satisfaction	HAPU prevalence rate fell from 21% to 4.0% and the ICU length of stay shortened from 7.6 to 5.2 days. After adjustment for primary diagnoses and illness severity, the intervention group was significantly less likely than the baseline group to develop HAPU [odds ratio (OR)=0.1, p<0.0001] and had a shorter ICU length of stay (OR=0.67, p<0.0001). Data entry regarding ulcer severity and body site increased, and the participants used PU Manager more than once a day for over 80% of eligible cases. Attitudes toward PU Manager were positive.	positive

Evidence Table 3: health IT and Safety of Care in Ambulatory Settings

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Abramson, et al. 2011 ¹³⁵	Pre-Post, N=21 health care providers N=6 adopters N=15 non-adopters N=481 patient adopters at baseline N=1,054 patient non-adopters at baseline N=368 patient adopters at one year N=963 patient non-adopters at one year	Outpatient/A mbulatory	non-leader, Commercial health IT	e-Prescribing	safety- med	statistically significant reductions in prescribing error	positive
Dainty, et al. 2011 ¹³⁹	Controlled Trial, 26=physician participants N=44 intervention weeks N=22 control weeks	Outpatient/A mbulatory	non-leader, Commercial health IT	e-Prescribing	safety- med	statistically significant increase in callback rate for prescription clarification	negative
Yu, et al. 2011 ¹⁴²	Pre-Post, Pre-intervention N=1,014 providers prescribed 31,118 medication orders with BBWs to 24,477 patients Post-intervention N=2,270 providers prescribed 63,010 medication orders with BBWs to 45,744 patients	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	safety- med	Non-adherence to drug-drug interaction warnings decreased 4.3% and non-adherence to drug-pregnancy interactions decreased from 1.5%	mixed- positive
Moniz, et al. 2011 ¹³⁶	Cntrl. Before/After , All prescriptions N=41,022 N=11,447 prescriptions written in Control Clinic N=29,575 written in the e- prescribing clinic	Outpatient/A mbulatory	Partners, Homegrown health IT Product	e-Prescribing	safety- med	statistically significant reductions in prescribing error	positive
Devine, et al. 2010 ¹³⁷	Pre-Post, Pre-CPOE N=5,016 Post-CPOE N=5.153	Outpatient/A mbulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Statistically significant reductions in prescribing error	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Abramson, et al. 2011 ¹⁴⁴	Time Series, N=17 physicians, N=646 patients at baseline; N=736 patients 12- weeks post transition; and N=715 patients 1-year post transition	Outpatient/A mbulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	safety- med	Prescription error rates dropped significantly, from 35.7 per 100 prescriptions at baseline to 21.1 12-weeks after transition to a newer EHR, and to 12.2 per 100 prescriptions 1-year after transition to a newer EHR.	positive
Allen, et al. 2012 ¹⁴⁶	Descriptive Quantitative, N=30,406 adult patients	Outpatient/A mbulatory	non-leader, Commercial health IT	e-Prescribing	safety- med	Researchers found that pharmacists still dispensed 1.5% of medications that had been discontinued in the EHR.	negative
Gonzalez, et al. 2012 ¹⁴⁰	Pre-Post, N=25,463 patients from the New York State AIDS Drug Assistance Program	Outpatient/A mbulatory	non-leader, Unspecified	Clinical Decision Support	safety- med	CDS alerts for antiretroviral drug interactions were associates with a 77% relative decrease in the rate of contraindicated antiretroviral drug combinations.	positive
Rappaport, et al. 2011 ¹⁴³	Time Series, N=2,745, 523 outpatient pediatric visits	Outpatient/A mbulatory	non-leader, Commercial health IT	Medication Lists	safety- med	EHR-based, outpatient pediatric quality improvement intervention was associated with significant improvement in the documentation of medication reconciliation. From 0% in 2005 to a maximum of 71% in 2010.	positive
Schnipper, et al. 2012 ¹⁴⁵	Controlled Trial, N=3,979 patients; N=11 PCP practices	Outpatient/A mbulatory	Partners, Homegrown health IT Product	Clinical Decision Support	safety- med	Use of a PHR was associated with a significant reduction in medication discrepancies (OR 0.71), a significant reduction in the potential risk for severe harm (RR 0.31).	positive
Kaushal, et al. 2011 ¹³⁸	Cntrl. Before/After, N=11 practices, N=21 providers	Outpatient/A mbulatory	non-leader, Commercial health IT	e-Prescribing	safety- med	Both stand alone and integrated e-prescribing systems were associated with significant reductions in medication error rates. The stand-alone system reduced error rates from 42.5 to 6.6 errors per 100 prescriptions. The integrated system reduced error rates from 26.0 to 16.0 per 100 prescriptions.	neutral
Tamblyn, et al. 2012^{141}	Controlled Trial, N=81 family physicians, N=5,628 patients	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	safety- med	CDS alerts targeting drug side effects reduced the risk of injury by 1.7 injuries per 1000 patients.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Falck, et al. 2013 ²³⁰	Cross-sectional, N=35,966 Alerts	Outpatient/A mbulatory	non-leader, Commercial health IT	Clinical Decision Support	safety- med	CDS using indication-based prescribing of antihypertensives produced accurate problem placement roughly two-thirds of time with fewer than 5% inaccurate problems placed. Performance of alerts was sensitive to the number of potential indications of the medication and attendings vs. other clinicians prescribing. Indication-based prescribing during CPOE can be used for problem list maintenance, but requires optimization.	mixed- positive

Evidence Table 4: health IT and Safety of Care in Non-ambulatory Settings

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Chen, et al. 2011 ¹⁶¹	Pre-Post, N=30 medical logic modules and N=110 order sets were developed to support pediatric oncology, during 9 months	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	37% reduction in chemotherapy dosing	positive
Appari, et al. 2011 ¹⁷⁶	Cross-sectional, N=2,603 hospitals N=1,790 eMAR hospitals N=919 CPOE hospitals	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	safety- med	14-29% increase in medication administration quality indicators	positive
FitzHenry, et al. 2011 ¹⁷⁷	Descriptive Quantitative, N=2,404 enrolled patients with warfarin orders N=18,393 warfarin doses ordered N=2,308 associated with error alerts	Non- Ambulatory	Vanderbilt University, Commercial health IT	Computerized Provider Order Entry	safety- med	Only 4% alerts for potential adverse events related to warfarin therapy were clinically meaningful.	negative
Zlabek, et al. 2011 ¹⁴⁷	Pre-Post, Pre-EHR N=1,325 hospitalizations/month N=4,985 patient days/month Post-EHR N=1,299 hospitalizations/month N-4,883 patient days/month	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Radiology orders, lab tests, and paper use decreased by 6.3%, 18%, and 27% respectively	positive
Traugott, et al. 2011 ¹⁵⁷	Pre-Post, N=200 patients N=100 patients in the pre-implementation group, analyzing N=310 serum vancomycin concentrations N=100 patients in the post-implementation group, analyzing N=235 concentrations.	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	safety- med	10% increase in adherence to antibacterial medication guidelines	positive
Warrick, et al. 2011 ¹⁶²	Pre-Post, N=54 chart evaluations N=624 prescriptions evaluations for errors N=1,022 regularly scheduled doses were assessed for omissions	Non- Ambulatory	UK's NHS, Commercial health IT	e-Prescribing	safety- med	6.7% reduction in omitted medication doses	positive
Morriss, et al. 2011^{174}	Cohort, N=618 patients	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	safety- med	Reduced risk of opioid related adverse events by approximately 50%	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Roberts, et al. 2010^{165}	Cntrl. Before/After , NR	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Significantly increased true positive rate of adverse drug event alerts	positive
Abdel-Qader, et al. 2010 ¹⁷⁰	Descriptive Quantitative, N=212 patients with prescribing errors	Non- Ambulatory	UK's NHS, Commercial health IT	e-Prescribing	safety- med	High rates of prescribing error in a UK teaching hospital despite the presence of e-prescribing.	negative
Strom, et al. 2010 ¹⁶⁹	Controlled Trial, N=1,971 UPHS randomized clinicians N=985 intervention clinicians N=986 control clinicians	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Hard-stop CDS alert resulted in unnecessary treatment delays for a number of patients	negative
Hill, et al. 2010 ¹⁷⁵	Pre-Post, Pre-Intervention N=724,465 ED specimens N=3,007 mislabeled Post-intervention N=334,039 specimens N=379 errors	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	74% relative decrease in specimen errors	positive
McCoy, et al. 2010 ¹⁵⁸	Pre-Post, Pre-intervention N=914 patients with N=1,920 orders Post-intervention N=745 patients with N=1,598 orders	Non- Ambulatory	Vanderbilt University, Homegrown health IT Product	Computerized Provider Order Entry	safety- med	17.4 % increase in the timeliness of medication discontinuation	positive
Mattison, et al. 2010 ¹⁶⁰	Pre-Post, NR	Non- Ambulatory	non-leader, Homegrown health IT Product	Computerized Provider Order Entry	safety- med	16% reduction in the number of potentially inappropriate medications	positive
Strom, et al. 2010 ¹⁶⁸	Controlled Trial, N=1,963 UPHS providers N=960 intervention providers N=1,003 control providers	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Active alert made no difference compared to a passive alert	neutral
Terrell, et al. 2010^{153}	Controlled Trial, N=42 physicians N=2,783 patient visits	Non- Ambulatory	Regenstrief, Homegrown health IT Product	Computerized Provider Order Entry	safety- med	31% reduction in excessive drug dosing	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Roberts, et al. 2010 ¹⁵⁹	Pre-Post, N=509 pre-intervention N=492 post-intervention	Non- Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	safety- med	47-86% improvement in dosing conformity for renal drugs	positive
Seidling, et al. 2010 ¹⁵²	Pre-Post, Phase 1, baseline assessment N=12,197 with dose regimen Phase 2, intervention phase N=11,714 with dose regimen	Non- Ambulatory	non-leader, Homegrown health IT Product	Clinical Decision Support	safety- med	1% reduction in excessive drug dosing	positive
Ali, et al. 2010 ¹⁶³	Time Series, N=14,721 prescriptions written in N=613 charts	Non- Ambulatory	UK's NHS, Commercial health IT	Computerized Provider Order Entry	safety- med	6.7% reduction in omitted medication doses in a pediatric ICU.	positive
Metzger, et al. 2010 ¹⁷²	Descriptive Quantitative, N=62 hospitals	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	CDS as implemented would have detected only 53% medication orders that would have resulted in fatal adverse events, and 10-82% of orders that would have caused serious adverse drug events.	negative
Wetterneck, et al. 2011 ¹⁷³	Pre-Post, N=4,147 patient-days pre-implementation and N=4,013 patient-days post- implementation	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Duplicate medication errors increased significantly after implementation of commercial COMPUTERIZED PROVIDER ORDER ENTRY system (2.6% pre, 8.1% post). Many work system factors, including the COMPUTERIZED PROVIDER ORDER ENTRY, CDS, and medication database design, contributed to their occurrence.	negative

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Cheng, et al. 2012 ¹⁵⁴	Pre-Post, N=18,690 prescriptions	Non- Ambulatory	non-leader, Homegrown health IT Product	Computerized Provider Order Entry	safety- med	The implementation of COMPUTERIZED PROVIDER ORDER ENTRY after the identification of several potential safety risks through healthcare failure mode and effect analysis was associated with significant decreases in chemotherapy prescription errors, from 3.34% to 0.40%.	positive
Hermsen, et al. 2012 ¹⁶⁶	Pre-Post, N=1,398 patients	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	safety- med	The implementation of CDS alerts to promote appropriate use of antibiotics was associated with a significant increase in the number antibiotic stewardship interventions; however, 30% of CDS alerts were judged redundant or clinically unimportant.	mixed positive
Taegtmeyer, et al. 2011 ¹⁴⁹	Cross-sectional, N=109 patients	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Patients with an electronic prescribing chart were 2.74 times more likely to have implemented pharmacist recommended medication changes implementation of the change than those with a paper prescription chart	positive
Daniels, et al. 2012 ¹⁵⁵	Pre-Post, N=146 patients	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Updating the COMPUTERIZED PROVIDER ORDER ENTRY system to include common dosage defaults for combination antiretroviral products was associated with a 57% reduction in the number of medication errors.	positive
Wang, et al. 2012 ¹⁵⁶	Pre-Post, N=38,647 antibiotic prescriptions were recorded in the COMPUTERIZED PROVIDER ORDER ENTRY system.	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	safety- med	COMPUTERIZED PROVIDER ORDER ENTRY with automatic dose calculation was associated with an 80% decrease in the rates of antibiotic dose errors, and the incidence of renal function deterioration decreased from 12.39% to 9.47%.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Miller. et al. 2011 ¹⁷¹	Cohort, N=137 Admissions, N=133 Unique Patients	Non- Ambulatory	VA, Homegrown health IT Product	Clinical Decision Support	safety- med	Despite the presence of CDS alerts designed to reduce drug-drug interactions for patients on Warfarin, 37% of the admissions studied had an ADE, and clinicians responded appropriately to CDS alerts in less than 20% of admissions. Increased number of non-critical CDS alerts was significantly associated with clinically non-appropriate responses to critical CDS alerts.	negative
Leung, et al. 2012 ¹⁶⁷	Pre-Post, N=2,000 charts at 5 MA hospitals	Non- Ambulatory	Partners, Commercial health IT	Computerized Provider Order Entry	safety- med	Adoption of vendor COMPUTERIZED PROVIDER ORDER ENTRY systems was associated with a decrease in the preventable ADE rate by 34%; however ADEs increased (14.6/100 vs. 18.7/100 admissions) overall. Findings suggest that the vendor COMPUTERIZED PROVIDER ORDER ENTRY systems can reduce drug-related injury and harm, but that refinements to the vendor applications and their associated decision support may be necessary.	mixed positive
Westbrook, et al. 2012 ¹⁴⁸	Pre-Post, N=3,291 admissions; 2 Australian hospitals	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Use of a COMPUTERIZED PROVIDER ORDER ENTRY system was associated with a statistically significant reduction in serious medication error rates ranging from reductions of 57-66% in two in selected wards of two Australian hospitals.	positive
Adelman, et al. 2012 ¹⁵⁰	Controlled Trial, N=4,028 providers	Non- Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	safety- med	Compared with control, a patient ID-verify alert reduced the odds of wrong patient orders (OR 0.84), and a patient ID-reentry function reduced the odds by a larger magnitude (OR 0.60).	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Muzyk, et al. 2012 ¹⁶⁴	Pre-Post, pre: N=84 patients; post N=67 patients	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	safety- med	A COMPUTERIZED PROVIDER ORDER ENTRY order set significantly improved the safety of intravenous haloperidol administration in medically ill patients.	positive
Hyman et al. 2012 ¹⁵¹	Cntrl. Before/After, N=1 hospital	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	A COMPUTERIZED PROVIDER ORDER ENTRY based intervention that included the use of patient pictures and verification screens were associated with the elimination of wrong patient-orders (from 24 to 0%).	positive
Westbrook, et al. 2013 ²³¹	Descriptive Quantitative, N=629 inpatient admissions at 2 hospitals in Australia	Non- Ambulatory	non-leader, Commercial health IT	e-Prescribing	safety- med	ERx system resulted in a net reduction of 220 prescribing errors per 100 admissions.	positive
Galanter, et al. 2013 ²³²	Cross-sectional, N=127,320 alerts fired	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	safety- med	Indication-based alerts yielded a wrong- patient medication error interception rate of 0.25 per 1000 alerts. These alerts could be implemented independently or in combination with other strategies to decrease wrong-patient medication errors.	mixed positive

Evidence Table 5: health IT and Efficiency of Care in Ambulatory Settings

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Adler-Milstein and Jha, 2012 ¹⁷⁸	Cross-sectional, N=200 physicians	Outpatient/ Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency-cost	Among physicians with EHRs, those with highly skilled, autonomous staff were seven times more likely to be top performing in terms of quality and efficiency than those without such staff.	positive
Pettit, et al. 2012 ¹⁷⁹	Pre-Post, N=400 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency-cost	A COMPUTERIZED PROVIDER ORDER ENTRY template for enoxaparin was not associated with about reductions in the daily cost of therapy.	neutral
Adler-Milstein, et al. 2013 ²³³	Descriptive Quantitative, N=49 physician practices	Outpatient/ Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency-cost	The average physician would lose \$43,743 over five years; just 27 percent of practices would have achieved a positive return on investment; and only an additional 14 percent of practices would have come out ahead had they received the \$44,000 federal meaningful-use incentive.	negative

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Adler-Milstein, et al. 2013 ²³⁴	Cntrl. Before/After, N=47,979 intervention patients and 130 603 control patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency-cost	Ambulatory EHR adoption did not impact total cost (pre- to postimplementation difference in monthly trend change, -0.30 percentage point; P = 0.135), but the results favored savings (95% CI, \$21.95 PMPM in savings to \$1.53 PMPM in higher costs). It slowed ambulatory cost growth (difference in monthly trend change, -0.35 percentage point; P = 0.012); projected ambulatory savings were \$4.69 PMPM (CI, \$8.45 to \$1.09 PMPM) (3.10% of total PMPM cost). Ambulatory radiology costs decreased (difference in monthly trend change, -1.61 percentage points; P < 0.001), with projected savings of \$1.61 PMPM (1.07% of total PMPM cost).	mixed-positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Ross, et al. 2013 ²³⁵	Pre-Post, N=306 providers in 69 practices for 34 818 patients	Outpatient/ Ambulatory	non-leader, Unspecified	Health Information Exchange	efficiency -cost	For primary care providers, the rate of laboratory testing increased over the time span (baseline 1041 tests/1000 patients/quarter, increasing by 13.9 each quarter) and shifted downward with HIE adoption (downward shift of 83, p<0.01). A similar effect was found for specialist providers (baseline 718 tests/1000 patients/quarter, increasing by 19.1 each quarter, with HIE adoption associated with a downward shift of 119, p<0.01). Even so, imputed charges for laboratory tests did not shift downward significantly in either provider group, possibly due to the skewed nature of these data. For radiology testing, HIE adoption was not associated with significant changes in rates or imputed charges in either provider group.	neutral
Bennett & Steen, 2010 ¹⁹¹	Pre-Post, N=7,446 visits performed by 11 faculty providers	Outpatient/ Ambulatory	non-leader, Commercial health IT	Summary of Care Records	efficiency -time	5% increase in the number of charts completed within 30 days	positive
Devine, et al. 2010 ¹⁸⁹	Pre-Post, Phase 1, N=69 subjects Phase 2, N=77	Outpatient/ Ambulatory	non-leader, Commercial health IT	e-Prescribing	efficiency -time	e-prescribing took 56% longer than longer hand writing a prescription.	negative

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Duffy, et al. 2010 ¹⁹⁰	Controlled Trial, N=24 nurses N=15 completed the admission process using the EMR POC documentation system N=9 completed the process using paper charting	Outpatient/ Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency -time	Nurses spent 90% (20.13 vs. 10.6 minutes) more time with their patients. However, while the absolute amount of time spent talking to the patient was 39% greater (5.85 vs. 4.2 minutes) than the control group, the relative amount of time that the nurse spent actually talking to the patient was less on a percentage basis (30% vs. 41%) and that using the point of care documentation was associated with prolonged pauses in which the nurse did not speak to the patient	mixed-positive
Bell, et al. 2012 ¹⁵	Controlled Trial, N=171 laboratory alerts	Outpatient/ Ambulatory	non-leader, Commercial health IT	Health Information Exchange	efficiency-time	Laboratory data exchange was associated with a significant reduction in the meantime that HIV therapies were appropriately changed from 37.7 days to 31.4 days after a brief period when the time to appropriate therapy increased.	mixed positive
Merrill, et al. 2013 ²³⁶	Pre-Post, N=1.7 million de- identified records, 217 primary care practices	Outpatient/ Ambulatory	non-leader, Commercial health IT	Electronic Immunization Registries	efficiency-time	Submissions within 14 days increased from 84% to 87%, and within 2 days increased from 60% to 77%. Median lag time decreased from 13 to 10 days. Documentation of eligibility decreased.	mixed positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Hayward, et al. 2013 ²³⁷	Cross-sectional, N=32 prescriptions were issued in the course of 73 of the consultations	Outpatient/ Ambulatory	UK's NHS, Commercial health IT	Clinical Decision Support	efficiency-time	CDSS alerts do not coincide with the prescribing workflow throughout the whole GP consultation. Current systems interrupt to correct decisions that have already been taken, rather than assisting formulation of the management plan.	negative
Maenpaa, et al. 2011 ¹⁸¹	Time Series, Hospital with medium-size population of about N=234,000 inhabitants	Outpatient/ Ambulatory	non-leader, Unspecified	Health Information Exchange	efficiency - utilization	3% and 1% reductions in primary care and emergency department visits respectively, but over the same period of time specialist visits increased by more than 10%	mixed-positive
Stenner, et al. 2010 ¹⁸⁷	Cntrl. Before/After , Total N=1,186,400 e- prescriptions N=170,751 Pre-implementation N=1,015,649 Post- implementation	Outpatient/ Ambulatory	Vanderbilt University, Homegrown health IT Product	e-Prescribing	efficiency - utilization	Generic drug use increased approximately 18%	positive
Furukawa, 2011 ¹⁸⁴	Cross-sectional, N=62,710 patient visits to N=2625 physicians	Outpatient/ Ambulatory	non-leader, Unspecified	e-Prescribing	efficiency - utilization	No association with diagnostic utilization for preventative care visits, but was associated with 7.1% fewer lab tests, and 7.3% fewer radiology orders for pre/post-surgery visits	mixed-positive
Duffy, et al. 2010 ¹¹	Descriptive Quantitative, Calls/1,000 Office Visits (n=number of calls) Before ERx Call N=1,101 Immediately after ERx call N=944 One year after ERx call N=990 Total N=3,035	Outpatient/ Ambulatory	non-leader, Commercial health IT	e-Prescribing	efficiency - utilization	High levels of patient and provider satisfaction	mixed-positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Ling, et al. 2010 ¹⁸²	Pre-Post, N=9,056 new patient visits N=3,624 period 1 N=3,931 period 2 N=1,501 period 3	Outpatient/ Ambulatory	non-leader, Unspecified	Patient Access to Electronic Records	efficiency - utilization	31% decrease in phone calls regarding test results.	positive
McCormick, et al. 2012 ¹⁸⁵	Cross-sectional, N=28,741 patient visits, N=1,187 physicians	Outpatient/ Ambulatory	non-leader, Unspecified	Clinical Lab Test Results	efficiency - utilization	Physicians' access to computerized imaging results was associated with a 40-70% greater likelihood of an imaging test being ordered.	negative
Palen, et al. 2012 ¹⁸³	Cohort, N=158,869 patients	Outpatient/ Ambulatory	Kaiser, Commercial health IT	Patient Access to Electronic Records	efficiency - utilization	Adoption of a PHR was associated with increased healthcare utilization. The study reported that the rate of office visits, telephone calls, after-hours visits, ED visits, and hospitalizations increased significantly more among PHR users.	negative
Lau, et al. 2012 ⁵⁸	Controlled Trial, N=742 patients	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Patient Care Reminders	efficiency - utilization	Patients with access to the PHR were 11.6% more likely to visit a health care provider during the study. The authors interpreted this finding as a positive result.	positive
Malhotra, et al. 2012 ¹⁸⁸	Pre-Post, N=886 clinicians, ~1 million prescriptions	Outpatient/ Ambulatory	non-leader, Commercial health IT	e-Prescribing	efficiency - utilization	Electronic prescribing interface redesign that required extra effort to prescribe branded drugs was associated with 36.9% percentage increase in the number of generic medications prescribed.	positive
Virga, et al. 2012 ⁶⁴	Pre-Post, N=3 clinics, N=263 patients	Outpatient/ Ambulatory	non-leader, Homegrown health IT Product	Health Information Exchange	efficiency - utilization	HIV/AIDS focused health information exchange was associated with significant increases in the number of medical visits (OR 1.96%).	mixed positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Solberg, et al. 2012 ¹⁸⁶	Time series, N=5 large medical groups of over N=6000 physicians	Outpatient/ Ambulatory	non-leader	Clinical Decision Support	efficiency - utilization	Aggregate ambulatory statewide orders for HTDI tests increased from 32 to 41 per 1000 members from 2003 to 2006 (9% per year) at which point the rate leveled off through 2010. This trajectory change was simultaneous with implementation of an electronic medical record– based decision-support system for all ambulatory HTDI orders from 45% of the physicians in the state, as well as a prior notification/authorization approach by payers for the rest of the HTDI orders.	positive
Hebel, et al. 2012 ²³⁸	Pre-Post, N=117,606 patients	Outpatient/ Ambulatory	Partners, Homegrown health IT Product	Health Information Exchange	efficiency - utilization	The introduction of an internal HIE was associated with a 52.6% relative decrease in the number of laboratory tests ordered for patients new to the provider when recent laboratory results were available from another institution.	positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Ross, et al. 2013 ²³⁵	Pre-Post, N=306 providers in 69 practices for 34 818 patients	Outpatient/ Ambulatory	non-leader, Unspecified	Health Information Exchange	efficiency - utilization	For primary care providers, the rate of laboratory testing increased over the time span (baseline 1041 tests/1000 patients/quarter, increasing by 13.9 each quarter) and shifted downward with HIE adoption (downward shift of 83, p<0.01). A similar effect was found for specialist providers (baseline 718 tests/1000 patients/quarter, increasing by 19.1 each quarter, with HIE adoption associated with a downward shift of 119, p<0.01). Even so, imputed charges for laboratory tests did not shift downward significantly in either provider group, possibly due to the skewed nature of these data. For radiology testing, HIE adoption was not associated with significant changes in rates or imputed charges in either provider group.	positive

AUTHOR/YEA R/REF	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Gonzales, et al. 2013 ²³⁹	Controlled Trial, N=33 primary care practices	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	efficiency - utilization	Compared with the baseline period, the percentage of adolescents and adults prescribed antibiotics during the intervention period decreased at the printed decision support intervention sites (from 80.0% to 68.3%) and at the computer- assisted decision support intervention sites (from 74.0% to 60.7%) but increased slightly at the control sites (from 72.5% to 74.3%).	positive
McGinn, et al. 2013 ²⁴⁰	Controlled Trial, N=984 patients	Outpatient/ Ambulatory	non-leader, Commercial health IT	Clinical Decision Support	efficiency - utilization	Providers in the intervention group were significantly less likely to order antibiotics than the control group (age- adjusted relative risk, 0.74; 95% CI, 0.60-0.92)	positive

Evidence Table 6: health IT and Efficiency of Care in Non-ambulatory Settings

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Zlabek, et al. 2011 ¹⁴⁷	Pre-Post, Pre-EHR N=1,325 hospitalizations/month N=4,985 patient days/month Post-EHR N=1,299 hospitalizations/month N-4,883 patient days/month	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - cost	75% reduction in transcription costs	positive
Furukawa, et al. 2010 ¹⁹²	Time Series, N=326 hospitals comprised N=2,828 hospital-year observations	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	efficiency - cost	Early stage health IT adoption was associated with greater cost inefficiency in medical surgical wards, while more sophisticated health IT systems was not significantly associated with cost efficiency	negative
Shapiro, et al. 2010^{210}	Pre-Post, NR	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency - cost	Comprehensive ED information system was associated with an average increase in charges per discharge of 69.4%	positive
Furukawa, et al. 2010 ¹²⁶	Time Series, N=326 short-term, general acute care hospitals in California N=2,828 hospital-year observations	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency - cost	Significant increase in hospital costs	negative
Himmelstein, et al. 2010 ¹¹⁶	Time Series, N=20,269 hospitals incl in HIMSS Survey between 2003-2007 N=16,991 hospitals incl in HIMSS Survey and Medicare Cost Report between 2003-2007	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency - cost	No significant association between health IT and hospital administrative or overall costs.	neutral
Rantz, et al. 2010 ¹²⁹	Cntrl. Before/After, N=18 nursing facilities	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency - cost	EHR with point of care charting was associated with cost increases of 9.6-12.5%	negative
Stokes- Buzzelli, et al. 2010 ¹⁹⁶	Pre-Post, N=36 patients	Non- Ambulatory	non-leader, Commercial health IT	Patient Lists By Condition	efficiency - cost	24% reduction in costs for frequent ED patients	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Eisenstein, et al. 2012 ¹⁸⁰ ,	Controlled Trial, N=20,180 patient	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	efficiency- cost	The intervention group in a study of a population-based clinical decision support system increased their use of outpatient services and total medical costs; whereas, the control group did not significantly increase their utilization or medical costs.	negative
Subramanian, et al. 2012 ¹⁹⁸	Controlled Trial, intervention: N=107,856 resident-days ; control: N=106,111 resident-days	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	efficiency- cost	CDS system for renal insufficiency in nursing homes was associated with a \$1391.43 reduction in annual costs (7.6% net reduction). The authors concluded that this was not enough to cover the costs of the intervention.	neutral
Teufel, et al. 2012 ¹⁹⁴	Cross-sectional, N=3,438 hospitals	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- cost	Hospitals with COMPUTERIZED PROVIDER ORDER ENTRY did not have significantly lower cost per pediatric case than hospitals that did not use COMPUTERIZED PROVIDER ORDER ENTRY.	neutral
Abbass, et al. 2012 ¹⁹³	Cross-sectional, N=3,368 Hospitals	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- cost	The study findings did not show significant financial savings or higher nurse productivity in hospitals with more health IT.	neutral
Teufel, et al. 2012 ¹⁹⁵	Cross-sectional, N=4,605,454 weighted hospital discharges.	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- cost	EMR was associated with an average 7% greater cost per case in pediatric inpatient care (\$146 per discharge).	negative
Sakowski, et al. 2013 ²⁴¹	Pre-Post, ~13,000,000 doses	Non- Ambulatory	non-leader, Unspecified	Barcode Medication Administration	efficiency- cost	\$2000 per moderate or severe safety event averted	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Georgiou, et al. 2011 ²⁰³	Pre-Post, aPTT and PPT/INR Test Requests, % Test Parameter 2005 N=16,740 2006 N=18,990 2007 N=19,693 2008 N=20,804 Median TAT Test Parameter 2005 N=16,630 2006 N=18,830 2007 N=19,416 2008 N=20,873	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - time	Turnaround times for PT and INR lab tests decreased by 25% and 32% respectively	positive
Refuerzo, et al. 2011 ¹²⁵	Pre-Post, N=154 pregnant women N=83 paper based order entry N=71 CPOE	Non- Ambulatory	non-leader, Unspecified	Computerized Provider Order Entry	efficiency - time	No association between CPOE and C- sections or length-of-stay.	positive
Spalding, et al. 2011 ²⁰⁴	Pre-Post, N=49,175 patients N=28,687 before CPOE N=20,488 after CPOE	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - time	ED LOS decreased by 23 minutes (~12%)	positive
Furukawa, 2011 ²⁰⁵	Cross-sectional, N=35,849 patient record forms from N=364 hospital-based EDs. Representing a national weighted population of N=119.2 million visits to N=4,654 EDs.	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency - time	22.4% shorter ED LOS and 13.1% shorter treatment time, but not associated with reduced rates of patients leaving without treatment	mixed- positive
Bernstein, 2010 ⁸⁴	Cohort, 272-bed tertiary care women's and children's hospital N=60 residents	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency - time	Increased satisfaction with the sign out process after the implementation and staff reported less time devoted to redundant data entry	positive
Mayer, et al. 2010 ²⁰⁷	Time Series, N=30,357 patients included	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - time	No evidence of a significant learning curve for residents as they began to use the ED's clinical information systems	neutral

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Munyisia, et al. 2011 ²⁰⁹	Time Series, N=472 activities at 3 months, N=502 at 6 months, and N=338 at 12 months after implementation	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency- time	Introduction of an electronic nursing documentation system did not reduce the proportion of time nursing staff spent on documentation.	neutral
Fernando, et al. 2012^{200}	Controlled Trial, N=224 patients	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency- time	Electronically delivered prescriptions significantly reduced the median pharmacy wait time.	positive
Spellman, et al. 2012 ²⁰⁶	Time Series, N=1 Emergency Department	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency- time	Patient LOS increased between 6 and 22% on average during EHR implementation; however, average LOS returned to baseline levels by 3 months.	negative
Blankenship et al. 2012 ²⁰⁸	Pre-Post, N=646 patients pre, N=592 patients post	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency- time	Implementation of COMPUTERIZED PROVIDER ORDER ENTRY did not significantly reduce the time to administration of pain medications to patients in the ED.	neutral
Westbrook, et al. 2013 ²⁴²	Cntrl. Before/After, N=129 doctors	Non- Ambulatory	non-leader, Commercial health IT	Medication Lists	efficiency- time	eMMS introduction did not result in redistribution of time away from direct care or towards medication tasks.	neutral
Cartmill, et al. 2012 ²⁴³	Pre-Post, N=87 orders pre, 202 orders post	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency- time	The overall turnaround time from ordering to administration significantly decreased from a median of 100 min before order management implementation to a median of 64 min after implementation.	positive
Cochran, et al. 2011^{130}	Pre-Post, N=21,202 pregnancies	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency - utilization	No significant changes in fetal outcome measures	positive
Adams, et al. 2011 ¹⁹⁹	Pre-Post, N=3293 control discharges N=3492 study discharges	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - utilization	48% reduction in transfusions in a pediatric intensive care unit	positive
Zlabek, et al. 2011 ¹⁴⁷	Pre-Post, Pre-EHR N=1,325 hospitalizations/month N=4,985 patient days/month Post-EHR N=1,299 hospitalizations/month N-4,883 patient days/month	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency - utilization	Significant reduction in adverse drug events	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Stokes- Buzzelli, et al. 2010 ¹⁹⁶	Pre-Post, N=36 patients	Non- Ambulatory	non-leader, Commercial health IT	Patient Lists By Condition	efficiency - utilization	Reduced the number of lab tests (-28%), ED visits (-25%) and treatment time (- 39%)	positive
Fernando, et al. 2012^{200}	Controlled Trial, N=224 patients	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency- utilization	Electronic prescribing was not associated with significant improvements in medication adherence.	neutral
Eisenstein, et al. 2012 ¹⁸⁰	Controlled Trial, N=20,180 patient	Non- Ambulatory	non-leader, Unspecified	Clinical Decision Support	efficiency- utilization	The intervention group in a study of a population-based clinical decision support system increased their use of outpatient services and total medical costs; whereas, the control group did not significantly increase their utilization or medical costs.	negative
Abello Jr., et al. 2012 ²⁰²	Pre-Post, N=48 patients	Non- Ambulatory	non-leader, Commercial health IT	Patient Lists by Condition	efficiency- utilization	A patient registry combined with patient specific care plans was associated with significant reductions in ED utilization (8.9 visits per year to 5.9 visits per year) among frequent users with psychiatric conditions.	positive
Connelly, et al. 2012^{133}	Cross-sectional, N=5,166 adults with heart failure in 3 metropolitan Emergency Departments	Non- Ambulatory	non-leader, Commercial health IT	Multifaceted health IT Intervention	efficiency- utilization	In two of the three EDs studied, the presence of a prior record in the EHR was associated with fewer laboratory tests (-4.6 and -14%) and medication orders (-33.6% and -21.3%).	mixed positive
Ben-Assuli, et al. 2012 ²⁰¹	Cross-sectional, N=3.2 million ED visits	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- utilization	This study reported that when EHR- based patient histories are viewed the likelihood of single-day inpatient admissions from the ED decreased by 16.2 % in a large integrated delivery system in Israel. Suggesting that the EHR contributes to improved admission decisions.	positive

AUTHOR/ YEAR/ REFERENCE	Study Design Sample Size	Setting	health IT Leader Commercial health IT	Meaningful Use Functionality	Outcome Type	Outcome Result	Outcome Summary
Speedie, et al. 2013 ²²⁷	Cross-sectional, N=3 EDs (13 227 patients total)	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- utilization	no impact on mortality; 7% fewer laboratory test orders at one ED and 3% fewer at another; fewer diagnostic procedures were performed at two of the sites. At one site 36% fewer medications were ordered. The odds of being hospitalized were lower for EHR patients at one site and hospital LOS was shorter at two of the sites. EHR patient ED LOS was 18% longer at one site.	mixed positive
Lee, et al. 2013 ²⁴⁴	Cohort, N=708 acute-care hospitals in the US from 2000 to 2007	Non- Ambulatory	non-leader, Unspecified	Multifaceted health IT Intervention	efficiency- utilization	Hospitals adopting EMR experienced 0.11 (95% CI: -0.218 to -0.002) days' shorter length of stay and 0.182 percent lower 30-day mortality, but a 0.19 (95% CI: 0.0006 to 0.0033) percent increase in 30-day rehospitalization in the two years after EMR adoption. The association of EMR adoption with outcomes also varied by type of admission (medical vs. surgical).	mixed positive
Feldman, et al. 2013 ²⁴⁵	Controlled Trial, N=458,297 Orders Intervention; 142,196 Orders Control	Non- Ambulatory	non-leader, Commercial health IT	Computerized Provider Order Entry	efficiency- utilization	For the active arm tests, rates of test ordering were reduced from 3.72 tests per patient-day in the baseline period to 3.40 tests per patient-day in the intervention period (8.59% decrease; 95% CI, -8.99% to -8.19%). For control arm tests, ordering increased from 1.15 to 1.22 tests per patient-day from the baseline period to the intervention period (5.64% increase; 95% CI, 4.90% to 6.39%) (P < .001 for difference over time between active and control tests).	positive

Health Information Technology: An Updated Systematic Review with a focus on Meaningful Use Functionalities - Disposition of Comments Report

Research Review Title: *Health Information Technology: An Updated Systematic Review with a focus on Meaningful Use Functionalities*

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ONC Comments

Reviewer	Comment Section	Page	Comment	Response
Mostashari, Farzad	General		It's good, well done.	None needed
Member of ONC Team	General		I read it on the plane, and had a few thoughts that I think are probably not appropriate at this stage to change the course of the study, but I'll share them anyway. I think it's probably a mistake to limit the review to MU functionalities as currently outlined. Eliminating consumer-facing applications also seems to limit the results unnecessarily, but I understand why that was done.	Per ONC COO approval review was limited to MU. No changes made.
Member of ONC Team	General		One major comment is that I think it would be great if they could create a table of MU functionalities and identify the key benefits they found associated with it along with citations. This would mean creating additional tables. A summary table that highlights the key benefits of MU functionalities would be really helpful. I can send more comments but at a high level the one about MU functionality is the key gap I think that would be helpful for ONC overall and the work of our office in particular.	Per the contract the current report is organized based on clinical setting and key aspects of care. The peer reviewed publication will be organized based on MU functionalities. In the mean time we will provide ONC with a full evidence table that is easily sortable by MU functionality
Member of ONC Team	Background and Introduction – Topic Refinement	Page 5	In terms of the 'key aspects' outlined on page 5, it distracted me that safety and quality were separated, since the IOM definition of quality includes safety. To me, the buckets would be quality, efficiency, then outcomes—health outcomes should not be included as an aspect of quality.	As these two comments illustrate, considering safety as part of or separate from quality is not something
Member of ONC Team	Results		I disagree about combining safety and quality. I think those are two distinct areas (related). The types of patient safety studies done with regards to medications are completely different from quality related studies. So, best to keep those separate, as it currently stands.	everyone agrees on. We've chosen, with input from our TEP and ONC staff to keep them separate.
Member of ONC Team	Methods		Points that should be addressed: It would be useful if they defined the "HIT leaders" concept, I'm not sure what they mean by that. And I know what they mean, but the 'commercial' and 'homegrown' types of HIT should also be better defined upfront	Leaders are defined in table 3.2.2. Added text on page 13 to state that they were determined by previous lit reviews.
Mostashari, Farzad	Results		How and why are they "more conservative" on what they call "mixed positive" than Buntin study?	Clarified. Only the definition of "positive" was more conservative, as pointed out in revised text.
Mostashari, Farzad	Results		Why group negative with neutral? There's a big difference. At least report separately.	Accepted, given the increased number of articles we are able to report each of the outcome-result classifications separately.

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Mostashari, Farzad	Results		What are dates of studies that would be eligible? Is it everything since Buntin? Not clear	Added text to clarify. The Buntin Review runs through Feb 2010. Our review begins Jan 2010. So there is a small overlap to ensure that there were no gaps.
Mostashari, Farzad	Results		what are trends that will be pointed to in what this study reports vs others? (Akin to buntin's finding that more studies done outside benchmark institutions) - more commercial products?	We expanded the conclusions sections to highlight several trends including more HIT literature, and more studies of commercial systems
Mostashari, Farzad	Results		one of the goals of meta-analysis like this is to minimize the publication bias of "man bites dog" journalism- and the interest in counter- intuitive findings. Over- reliance on the author's interpretation of their findings can play into this unfortunately- so it's not necessarily right to interpret as negative if the author says "only 3 percent improvement, not meaningful" or "only 42% response" or "only 50% of errors would be caught".	The characterization of the results of any particular study – which may have measured multiple outcomes – into a single summary category ("positive," "mixed positive" etc.) is inherently a subjective judgment. In making these judgments, we considered not only how the results were characterized by the original authors, but also the size of the effect and the number and criticality of the outcomes.
Mostashari, Farzad	Results		I thought there were more cost studies than the 2 listed- (eg the Minnesota CDS for high cost imaging in AJMC).	The update process identified several cost related studies (including the one mentioned). These studies have been added to the review.
Mostashari, Farzad	Evidence Tables	Starting page 6	would be good to have a table of study characteristics and cross-tabs that also lists The number of patients involved (smaller studies can have non-significant or spurious findings more an large ones)	Agreed, those details are now in the evidence tables.

TEP Comments

Reviewer	Comment Section	Page	Comment	Response
George Hripcsak	General		You mention Kaiser in several places and Cleveland Clinic. Did they fund the study? It seems odd to advertise them but not anyone else. Either mention all the institutions or none of them.	Specific mentions of organizations have been removed
Louise L. Lang	General		Overall, I have no concerns related to your three questions. In general, I want to reinforce the importance of the organizational and financial context in achieving improvement with the EHR and the need for research that focuses on the cost impact and factors in success. In addition, I made a few minor comments/corrections (my title) in the attached draft. They are on pages iv, vi, 3, 7, 30, 31, and 38. Thank you for including me in this process and I hope that this report will further understanding and support for the leveraging of the EHR/PHR to improve US healthcare.	None needed (Title corrections made and comments addressed individually). In particular we tried to emphasize the importance of financial context.
George Hripcsak	Structured Abstract and Methods	Page v and Page 6	You mention inter-rater agreement but I do not remember seeing it reported. Either report the agreement or drop the mention.	Agreed, we have dropped the reference to inter-rater agreement.
Louise L. Liang	Structured Abstract - Conclusions	Page vi	The relationship between HIT and efficiency is complex and remains poorly documented or understood, particularly in terms of healthcare costs, which are highly dependent upon the care delivery and financial context in which the technology is implemented.	Word additions accepted
George Hripcsak	Background and Introduction – Topic Refinement	Page 5	Does the focus on the three questions on page 5 mean that the new review cannot be compared to the previous reviews anymore? (That is, because different types of articles were selected.) That is not necessarily bad, but I am curious.	We don't think that any differences between the prior reviews by Chaudhry, Goldzweig or Buntin and this review are primarily in the types of articles selected (most are hypothesis-testing articles) but rather in how the HIT system is characterized. This reflects how HIT is changing over time. We think each review is comparable to prior reviews, and the way HIT is classified is an important part of that comparison.

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David Bates	Background and Introduction – Summary of Previous Systematic Reviews	Page 2	Key findings from systematic review by Buntin: "64% of studies came from single- site implementations or tightly integrated networks -> Comment: Differentiate those	Agree that would be good, but Butin doesn't differentiate in her paper and we are just quoting her key finding here.
George Hripcsak	Methods / Results	Page 8 and Page 10 onwards	You explicitly point out the Stage 1 Meaningful Use functions, which made me worry that you excluded all other functions. Figure 1 seemed to confirm that with its "Advanced HIT" (N=29) box of rejected abstracts. The problem is that Stage 2 and 3 involve advanced HIT, such as documentation and care plans, and it is very important to have a review of those functions. That is where we are currently making decisions. Reading further into the paper, I see that documentation was included (perhaps as an outcome instead of as an intervention) as was eMAR. If that is the case, then be clear about what you included and excluded and explain what was rejected in Advanced HIT. I would have liked to see advanced forms of HIT in the review.	Removed mention of "advanced HIT" and clarified what kinds of studies we excluded: "e.g., a hospital syndromic surveillance system; configurable order set software to support clinical trials, implementation of health IT in an Iranian neonatal unit; use of personal health records in sub-Saharan Africa)"
Louise L. Liang	Methods – Inclusion/Exclusion Criteria	Page 7	"Articles that focused on consumer targeted HIT applications (e.g., an online food and exercise journal for diabetics)" Comment: This is confusing since the PHR fits this description	We only included PHRs that involved a provider in addition to a patient. Added "on a standalone website" to make this more clear.
David Bates	Results		I would also note somewhere that the meaningful use criteria were not developed in a vacuum and that the meaningful use committee intentionally prioritized items that were evidence-based, as the underlying intent is to improve care.	Added this text in chapter 1 "The meaningful use criteria are useful for defining the scope of this literature review because they were developed with the intention of improving care considering the current state of health IT functionality. "

Reviewer	Comment Section	Page	Comment	Response
David Bates	Results		The prior data suggest that the impact of CDS vary quite a bit by condition, to the extent that it may not be possible to generalize from one chronic condition to another, at least very much. This implies that it will be important to study how to implement CDS to some degree condition by condition.	Added this to limitations section: A fourth limitation is that many of the studies were specific to one clinical conditions or setting and therefore may not be generalizable for every application of the functionality. For example, the impact of CDS may vary quite a bit by condition. Future studies should try to understand the success factors for HIT functionalities across diverse settings and conditions.
David Bates	Results		There are also some data that discuss how to deliver decision support, that demonstrate that doing it while for example following human factors principles is more likely to be successful that not. It would also be worth alluding to this. Both having good content and delivering in ways that adhere to principles probably matter.	We allude to this in the provider satisfaction outcomes and also added this text: "HIT functionality designed according to human factors principles will be more likely to succeed, and future studies should design interventions according to these principles."

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George Hripcsak	Results		Did you notice whether some non-HIT side interventions (e.g., training) were predictive of success?	One would expect this to be true. Certainly having sufficient training time is a contextual feature thought to predict HIT success. However, we find that many hypothesis testing studies do not provide much description of training or other complementary factors that would likely impact the success of the system, We advocate in the conclusion that hypothesis testing studies should provide details of context and commentary on why the implementation was a success or failure.
George Hripcsak	Results		Are you going to report CIs on the estimates? Would be helpful when N is 6, for example.	We don't report CIs, but do report sample sizes in the evidence tables.
George Hripcsak	Results	Results Page 12	On page 12, you mention functions that were not studied. I wonder if some of them were studied indirectly. No one is going to launch a study of recording demographics, but those demographics may get used in CDS and elsewhere.	Agree, we have added language indicating that these functionalities, while not studied directly were likely part of the larger categories (e.g., CDS)
George Hripcsak	Results	Page 13	The definitions of positive and negative were a little confusing. Positive mixed includes studies where the author said positive outweighed negative. Negative includes studies that were mixed but were overall negative. What about the rest of the mixed results? E.g., mostly positive but the author did not say so. Or evenly mixed positive and negative.	We have added language to clarify the categorization.
George Hripcsak	Results	Results Page 15, Table 3.2.7	Page 15 says pre-post studies were 93% positive but Table 3.2.7 says cross sectional studies were 93% and pre-post were 67%.	Thanks for pointing out the discrepancy, these numbers have been reconciled and updated based on the update searches

Reviewer	Comment Section	Page	Comment	Response
George Hripcsak	Results	Results Page 17	I want to see not just positive and negative but a graphical summary of effect sizes. I know you are not doing a meta-analysis, but a mere statement of positive and negative misses the problem of inconsequential effects (which you rightly point out on page 17). So I am not trying to combine evidence but just visualize it. You could produce a graph that shows a box plot of pre- and post-intervention compliance rates. Or a graph that shows a set of line segments, where each segment connects the pre to the post level	This is a great suggestion in principle. In fact, it was our goal at the outset of the project. The problem is that the data are too challenging to fit into this format. These challenges include: 1) selecting one (or at most two or three) outcomes from a study that may have reported multiple outcomes 2) trying to group outcomes together that are conceptually related. For example, we wouldn't put in the same graph outcomes about quality and about patient satisfaction. But even within quality outcomes, is it clinically meaningful to include on the same graph outcomes on appropriate antibiotic prescribing, notification of pathology results, increasing the use of alpha (I)- antitrypsin deficiency screening, and "adherence to recommended preventive care guidelines"? We judged these to be too dissimilar to include on one graph. Then there are studies that report the results as odds ratios instead of proportions. The conclusion we reached is that to plot the results of studies into graphs would require lots of graphs with only a few studies in each graph, and this would not greatly aid readers in making comparisons across studies.

Reviewer	Comment Section	Page	Comment	Response
David Bates	Results	Page 19	Five studies evaluated the effects of multifaceted HIT interventions on process quality. Three studies found that multifaceted HIT interventions were associated with significant improvement in process quality. However, two analyses of large survey datasets reported that the availability of HIT was not associated with better process quality. Comment: these findings not really contribute in big datasets for data about what decision support is actually in place. Comment: that impact of CDS has varied greatly by condition, it can't really come up as one answer for this.	Agree, we have added text to address this issue. "Because these studies relied on large survey data, they could not consider how the various forms of HIT were implemented, not could they distinguish between various forms of CDS used. Also, these in these cross- sectional studies, there is limited ability to attribute causation."
David Bates	Results	Page 20	Two other cross-sectional studies evaluated the relationship between the HIT and standard quality measures using data from large surveys. The first study analyzed data from the National Ambulatory Medical Care and National Hospital Ambulatory Medical Care Surveys and found no consistent relationship between EHRs, CDS and better process quality. ⁷² The other analyzed data from a survey of 108 California physicians organizations and reported no correlation between EHR capabilities and composite quality measures for diabetes management, processes of care, and intermediate outcomes. ⁷³ Comment: For both need to say what they knew about CDS in place	Agree we have added text that highlights this limitation of these studies. In addition to problems knowing what the CDS consist of, the other major limitation of these cross-sectional studies is that there is no ability to attribute causation to the use of the CDS.
George Hripcsak	Results – Narrative Summary	Page 30	On cost, you need to clarify the difference between increased costs due to paying for the EHR (and training, staff inefficiency, etc.) versus increased health care system costs due to increased billing.	We distinguish these in specific studies.
Louise L. Liang	Results – Narrative Summary	Page 30	"The authors concluded that early stage HIT adoption was associated with greater cost inefficiency in medical surgical wards, while more sophisticated HIT systems was not significantly associated with cost efficiency." Comment: Efficiency or inefficiency?	The text is correct as stated.
Louise L. Liang	Results – Narrative Summary	Page 31	"This study reported that HIT was not significantly associated administrative or overall costs," Comment: unclear	Thanks for pointing this out, the text has been clarified
George Hripcsak	Results - Summary		Define non-ambulatory. Does it include care at home (i.e., patient could not ambulate to the clinic)? Or is it just inpatient? Or ED? Nursing home?	Yes, Non-ambulatory= Inpatient, ED, nursing homes. However, We didn't find any home care articles in this study.

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George Hripcsak	Conclusion - Summary	Page 38	Your last conclusion sentence asks for more studies that describes why systems fail, but didn't you exclude studies that looked at success and failure factors (methods section).	Studies assessing success or failure factors were included if they included outcomes of interest – quality, safety, satisfaction, etc. However, if the "outcome" was only that the EHR was implemented, without any assessment of an effect on a patient outcome, then it was rejected. We have clarified the text.
Louise L. Liang	Conclusion - Summary	Page 38	which are highly dependent upon the care delivery and financial context in which the technology is implemented.	Word additions accepted

Grammar and Editing Typos

Reviewer	Comment Section	Page	Comment	Response
ONC Team	Throughout report		HIT should be Health IT.	Correction made
George Hripcsak	Throughout report		Don't -> do not	Correction made
George Hripcsak	Structured Abstract	Page V	Abstract's conclusion: there is a semicolon that may need to be a colon.	Correction made
David Bates	Results	Page 18	Space between across and 19; insert "of" between 10.2% alerts	Correction made
David Bates	Results	Page 19	First sentence under "Multifaceted HIT Interventions" Five Studies -> studies; in process quality; however "quality. However"	Correction made
David Bates	Results	Page 21	Space between 36%) in	Correction made
David Bates	Results	Page 22	Last paragraph: measures, and all found	Correction made
David Bates	Results	Page 24	Mortality	Correction made
George Hripcsak	Results	Page 25	Page 25: bot -> both	Correction made
George Hripcsak	Results	Page 30	Page 30 focused on in hospital settings (?)	Deleted "in"
George Hripcsak	Results / Summary: All Care Settings		Page 33: layering technology ON a dysfunctional	Correction made
Louise L. Liang	Technical Expert Panel	Page iv	Add the word "retired" behind title	Correction made
Louise L. Lang	Background and Introduction – Topic Refinement	Page 3	Change of title to: Retired Senior Vice President, Quality and Clinical Systems Support, Kaiser Permanente	Correction made