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The Benefits Of Health Information Technology: A Review Of The Recent Literature Shows Predominantly Positive Results

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ABSTRACT An unprecedented federal effort is under way to boost the adoption of electronic health records and spur innovation in health care delivery. We reviewed the recent literature on health information technology to determine its effect on outcomes, including quality, efficiency, and provider satisfaction. We found that 92 percent of the recent articles on health information technology reached conclusions that were positive overall. We also found that the benefits of the technology are beginning to emerge in smaller practices and organizations, as well as in large organizations that were early adopters. However, dissatisfaction with electronic health records among some providers remains a problem and a barrier to achieving the potential of health information technology. These realities highlight the need for studies that document the challenging aspects of implementing health information technology more specifically and how these challenges might be addressed.

Health information technology (IT) has the potential to improve the health of individuals and the performance of providers, yielding improved quality, cost savings, and greater engagement by patients in their own health care.¹ Despite evidence of these benefits,² physicians' and hospitals' use of health IT and electronic health records is still low.^{3,4}

To accelerate the use of health IT, in 2009 Congress passed and President Barack Obama signed into law the Health Information Technology for Economic and Clinical Health (HITECH) Act, as part of the American Recovery and Reinvestment Act. HITECH makes an estimated \$14–27 billion in incentive payments available to hospitals and health professionals to adopt certified electronic health records and use them effectively in the course of care.¹ The legislation also established programs within the Office of the National Coordinator for Health Information Technology to guide physicians, hospitals, and

other key entities as they adopt electronic health records and achieve so-called meaningful use, as spelled out in federal regulations.⁵

The legislation and subsequent regulations were designed to spur adoption and yield benefits from health information technology on a much broader scale than has been achieved to date. Building on that effort, the Affordable Care Act of 2010 underscored the importance of health IT in achieving goals related to health care quality and efficiency.

Specifically, establishing the Center for Medicare and Medicaid Innovation emphasized the importance of identifying and testing innovative payment and care delivery models. Many of the payment and care delivery model opportunities in the legislation, and in the initial projects specified by the Innovation Center, require an information technology infrastructure to coordinate care. For example, the medical home demonstrations project in federally qualified health centers that is an initial focus of the Innovation

Center requires electronic record keeping, communication with patients, and e-prescribing.

Earlier reviews of the effects of health IT have found some evidence of the benefits of the technology. The reviews also revealed that benefits accrued more often to large organizations that were early adopters of health information technology. As a result, an important question is whether or not new evidence suggests that benefits might be more widely attainable than previously thought. This review will update policy makers, innovators, health IT users, and those contemplating adoption on the newer literature about the technology's effects on care delivery and on provider and patient satisfaction.

Study Data And Methods

Two previous articles presented results from systematic reviews of the peer-reviewed literature from 1994 to June 2007. Basit Chaudhry and colleagues⁶ covered articles from 1995 to January 2004, and Caroline Goldzweig and colleagues² examined articles from June 2004 to June 2007. We used the methods and selection criteria of these two studies to update their findings on the effects of health IT for the period July 2007 up to February 2010.

Other reviews evaluating effects of health information technology exist; our study turned up thirty-four during this period. But these reviews do not address the same set of health IT functionalities as the articles by Chaudhry and Goldzweig and their colleagues. Similar to those two earlier reviews, we tried to be as comprehensive as possible and included peer-reviewed publications assessing effects of electronic health records; computerized provider order entry; clinical decision-support systems; health information exchange; e-prescribing for outpatients; patients' personal health records; patient registries; telemedicine or remote monitoring; information retrieval; and administrative functions.

Using the same criteria as in the reviews by Chaudhry and Goldzweig and their colleagues, we searched the online journal database MEDLINE for the period July 2007 up to February 2010. The search resulted in a baseline of 4,193 articles. Exact search terms and an "evidence table" depicting study purpose, clinical setting, areas of health IT addressed, outcomes measured, and findings are provided in the online Appendix.⁷

Following Chaudhry and Goldzweig and their colleagues, we decided that to be included in this review, an article had to address a relevant aspect of health IT, as listed in the Appendix;⁷ examine the use of health information technology in clinical practice; and measure qualitative or quanti-

tative outcomes. Analyses that forecast the effects of a health IT component were included only if they were based on effects experienced during actual use. Evaluations of health IT components not used in clinical practice were dropped. For example, a retrospective analysis of strategies to identify hospitalized patients at risk for heart failure was excluded because the methods were not implemented in a hospital.⁸

Using this framework, the review team removed 2,692 articles based on their titles. An additional 1,270 articles were determined to be outside the study's scope after the team examined the article abstracts. For example, 269 abstracts focused solely on health IT adoption. By the third review stage, the review team had 231 articles. An additional forty-three were excluded after further review because they did not meet the criteria, and thirty-four review articles were dropped from the analyses because they did not present new work. This left 154 studies that met our inclusion criteria, 100 of which were conducted in the United States. This is comparable to the 182 studies found over a slightly longer time period that were evaluated by Goldzweig and colleagues.²

CLASSIFYING STUDIES Studies were classified by study design, care setting, health IT components, functions included in the meaningful-use criteria, and outcomes addressed.⁵ In terms of study design, there were sixty-five that tested hypotheses quantitatively; fifty descriptive studies with quantitative results; thirty-two descriptive qualitative studies; three case studies; and four predictive studies. Two different members of the review team classified each article. Differences between first and second abstractions were discussed. Final decisions involving 16 of the 154 articles were made by the study leader, Melinda Beuwkes Buntin.

Discussions of the health IT systems in the literature usually were not specific enough to determine precisely which meaningful-use criteria were met. As a result, we tracked the components that were included in the criteria to the best of our abilities and coded only those functions that were explicitly mentioned in the articles. Articles were also categorized by overall conclusion as either: positive, mixed-positive, neutral, or negative. In addition, each outcome measure within each article was classified into one of the four categories.

Positive articles and outcomes were ones in which health information technology was associated with improvement in one or more aspects of care, with no aspects worse off. In articles that tested for significant differences, the improvements were statistically significant; in other articles, findings were classified as positive if they

were portrayed as improvements by the authors.

For a neutral rating, health information technology was not associated with any demonstrable change in care or care setting according to the criteria above.

To earn our mixed-positive rating, either the authors had to draw a positive conclusion overall in the abstract or conclusion, or, in the absence of a summary judgment, our best assessment of the evidence presented in the article had to be that the positive effects of health IT outweighed the negative effects. However, the article or outcome, or both, had to include at least one negative aspect. Articles in this category had roughly three positive outcomes for every negative outcome (data not shown).

We created a mixed-negative rating for articles or outcomes with overall negative conclusions but positive aspects. However, we found so few mixed-negative and negative outcomes that we categorized them together as negative. In negative articles, therefore, health information technology was associated with at least one outcome's being worse off.

For articles that evaluated multiple outcomes, we also assigned multiple outcome categories. For example, a study that assessed the effect of a health IT system on both quality (effectiveness) and cost (efficiency) of care was assigned individual effectiveness and efficiency conclusions and an overall conclusion.

Under this system, it is still possible to have a mixed result with respect to the effect of information technology on the individual measure in question. For example, a study that assessed the efficiency effects of a health IT implementation could find that it both decreases transcription costs yet increases the time physicians spend performing administrative functions related to the electronic health record.

We acknowledge the shortcomings of categorizing often nuanced findings. It is also rarely possible to capture every effect of implementing IT in a peer-reviewed publication. We felt, however, that this rating system allowed us to aggregate the studies' findings in a useful way.

Our criteria differed in two respects from the earlier reviews. First, we included descriptive qualitative studies in order to capture focus-group reports, studies using qualitative interviews, and firsthand assessments of health IT implementations, which we considered important evidence when aggregated as in this study. Second, we excluded systematic reviews, because we reasoned that such reviews would cover articles already included in our review or in prior reviews. The opposite choice was made in a recent review of review articles published by Ashley Black and colleagues.⁹

Had we followed the exact methodology prescribed by Goldzweig and colleagues,² thirty-two descriptive qualitative studies would have been dropped, and thirty-four systematic reviews would have been included. However, applying their methodology would not have altered qualitatively any of the overall findings described below.

LIMITATIONS Our findings must be qualified by two important limitations: the question of publication bias, and the fact that we implicitly gave equal weight to all studies regardless of study design or sample size. We elaborate on both below.

► **PUBLICATION BIAS:** First, publication bias is always a concern when conducting a review. This bias exists in two forms: Negative findings are not published as often; and potential negative effects are not always sought or uncovered. A recent study found that for clinical trials, studies with positive results are roughly four times more likely to be published than those without positive findings.¹⁰

Because the articles were limited to health IT adopters, we anticipated that authors more often approached studies looking for benefits rather than adverse effects. Similarly, we relied on the standards of the journals in which the studies were published to weed out situations in which financial relationships existed between the authors and the systems evaluated, but it is possible that ongoing vendor relationships would affect decisions to publish.

It is important to note that although publication bias may lead to an underestimation of the trade-offs associated with health IT, the benefits found in the published articles are real.

► **EQUAL WEIGHT:** Second, as noted above, we implicitly gave equal weight to all studies, regardless of study design or sample size. We did this, however, with the realization that any method of weighting the evidence would be subjective, given the wide variation in settings and outcomes covered by this review. Hence, when discussing the evidence, we took into account—but did not attempt to formally weight—factors that can increase the generalizability of the evidence, such as sample size, inclusion of multiple measures, and use of statistical methods.

Results

Of the 154 included studies, 96 (62 percent) were positive, which means that health information technology was associated with improvement in one or more aspects of care, with no aspects worse off; and 142 (92 percent) were either positive or mixed-positive. As described in more detail above, mixed-positive articles or outcomes

were those in which the authors drew a positive conclusion overall but the article demonstrated at least one negative aspect of health information technology. These 154 studies tracked 278 individual outcome measures. Of these measures, 240 (86 percent) had at least mixed-positive outcomes (Exhibit 1).

POSITIVE FINDINGS In the 92 percent of articles with positive overall conclusions, most either used statistical methods to test hypotheses (sixty-two studies) or were descriptive studies that included quantitative findings (forty-five studies). Indeed, studies using statistical methods to test hypotheses, assessing two or more outcomes of health IT use, or including efficiency or effectiveness were more likely to have positive conclusions than those that did not (Exhibit 2).

For example, studies that used statistical hypothesis testing were more than twice as likely (2.1 times greater) to produce an overall positive conclusion compared to those that did not use statistical hypothesis tests. Studies that assessed provider or staff satisfaction were less likely to reach positive conclusions than those that did not, as were descriptive studies, as indicated by an odds ratio less than 1. In these studies, providers often cite unsatisfactory technology or technology support as barriers to adopting and realizing the benefits of health IT.^{3,4,11,12}

Of the eighteen qualitative articles that did not address provider or staff satisfaction, sixteen had at least mixed-positive conclusions overall. Most negative findings within these articles relate to the work-flow implications of implementing health IT, such as order entry, staff interaction, and provider-to-patient communication.

We also found that articles addressing more health IT functionalities included in the meaningful-use regulation⁵ had slightly higher numbers of positive findings on individual measures (0.2 more positive findings on average, $p < 0.05$) compared to articles that did not address such functionalities. This was not because of the statistical artifact of articles' including more meaningful-use criteria that incorporated more measures (and thus more positive ones), so this is limited evidence that addressing meaningful-use criteria yields positive benefits.

We included fourteen studies assessing both quality and efficiency outcomes, none of which was categorized as negative overall. Eleven of the fourteen used statistical methods to test hypotheses.

Among these fourteen articles, one study found that patient mortality and nurse staffing levels decreased by as much as 48 percent and 25 percent, respectively, in a three-year period after three New York City dialysis centers implemented an electronic health record.¹³ Another

study found that clinical decision support decreased the amount of time dialysis center staff spent with patients for anemia management by nearly 50 percent, but clinical outcomes were maintained.¹⁴

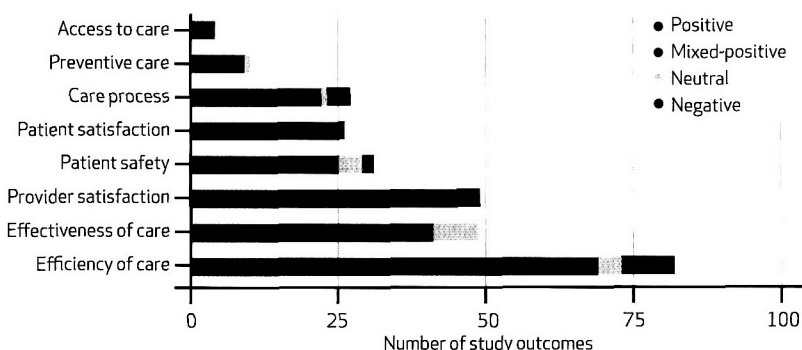
On the inpatient side, a clinical decision-support tool designed to decrease unnecessary red blood cell transfusions reduced both transfusions and costs but did not increase patients' length-of-stay or mortality.¹⁵ A study addressing health IT in forty-one Texas hospitals found that hospitals with more-advanced health IT had fewer complications, lower mortality, and lower costs than hospitals with less-advanced health IT.¹⁶ On the negative side, one of these articles reported that "most wired" hospitals had higher costs than those less wired during the study period, although mortality was lower for heart attack patients in these hospitals.¹⁷

We included sixty-nine studies that assessed electronic health records, forty-four that addressed computerized provider order entry, and forty-four that assessed clinical decision-support systems (categories are not mutually exclusive, which accounts for the fact that the total exceeds the number of articles included in our study). These represent increases in the number of articles with these functionalities over those found by Goldzweig and colleagues.²

There was also suggestive, but not significant ($p < 0.10$), evidence that studies assessing more complete electronic health records, compared to specific health IT tools, were more likely to reach more positive findings (data not shown). Of the included studies, fifty-four evaluated health information technology outside the United States. International studies were no more positive or negative than those from the United States (data not shown).

EXHIBIT 1

Evaluations Of Outcome Measures Of Health Information Technology, By Type And Rating



SOURCE Authors' analysis of published peer-reviewed studies. **NOTE** A total of 278 outcome measures were evaluated across all studies included in our final sample.

EXHIBIT 2

Health Information Technology: Study Design And Scope Factors Associated With Positive Overall Conclusions

	Number of applicable articles	Odds ratios for overall positive effect	p value
STUDY DESIGN			
Statistical methods used to test hypotheses	65	2.13	0.03
Descriptive, qualitative	32	0.38	0.02
MEASUREMENT			
Included two or more outcome measures	67	2.39	0.001
Included efficiency effects as a measure	73	2.34	0.01
Included effectiveness/quality effects as a measure	45	2.75	0.01
Included provider/staff satisfaction as a measure	44	0.16	0.001

SOURCE Authors' analysis of published peer-reviewed studies. **NOTES** Odds ratios compare the odds of a positive overall finding for the category shown against the relevant reference group. The reference groups are as follows. For hypothesis tests: descriptive studies (qualitative or quantitative), case studies, or predictive analyses; for descriptive qualitative studies: hypothesis tests, descriptive studies with quantitative results, case studies, or predictive analyses; for measurement variables: included less than two outcome measures, did not include efficiency effects, did not include effectiveness/quality effects, did not include provider/staff satisfaction.

NEGATIVE FINDINGS We categorized ten studies as containing negative overall findings. These represent potential problems associated with the implementation and use of health information technology. Two of these studies used statistical methods to test hypotheses; four of them were qualitative in nature. In addition, negative articles addressed fewer meaningful-use criteria than did articles with neutral, mixed-positive, or positive overall conclusions (data not shown).

Of the two negative articles testing hypotheses, one evaluated e-prescribing at three ambulatory care sites. After the site was adjusted for, e-prescribing took marginally longer than handwritten prescriptions. However, the article did not evaluate the accuracy of prescription orders from the electronic application versus a paper-based method.¹⁸ The second article evaluated associations between patient factors and using health information exchange to access patient data. The study concluded that providers' use of health information exchanged with other providers was positively correlated with patients' prior utilization, chronic conditions, and age. In other words, providers were more likely to access information via exchanges for higher-risk patients than for those who received less-frequent care. As a result, the authors concluded that expectations of use reductions from health information exchanges may have to be re-examined.¹⁹

Among the descriptive studies with negative conclusions, one evaluated the implementation of health IT in a small rural hospital. According to the authors' assessments, the hospital faced a lack of clinical leadership, staff skepticism, lead-

ership turnover, an unrealistic schedule, and a vendor whose products were not ready on time. The implementation was associated with an increase in patient care errors, including medication errors, procedure errors, and patient falls. Had the IT system been better planned and implemented, the authors believe that these pitfalls could have been avoided.²⁰

Another article found that use of an electronic health record inhibited interaction during ward rounds compared to use of paper charts.²¹ Two negative studies addressed electronic orders. One qualitative study found that work-flow problems emerged at an Australian pathology lab after the lab began receiving orders electronically.²² In a second qualitative study at an Australian emergency department, providers believed that the computerized provider order entry system was not usable, did not meet their expectations, and improperly altered their responsibilities.²³

The remaining negative articles addressed other issues. A US study addressing a clinical decision-support system for depression found, in pilot testing, that variability in computer literacy and information systems led to unsuccessful implementations.²⁴ After adopting electronic health records, some Norwegian physicians found that the overall availability of patient records improved but that the comprehensiveness of information within each record, especially for chronically ill patients, was worse.²⁵

A study in the Netherlands focused on the outcomes of implementing computerized provider order entry in six internal medicine wards of an academic medical center. The article found that

nurse-physician medication collaboration was impaired by the implementation of computerized provider order entry.²⁶ A study in New Jersey after the state implemented electronic reporting for suspected Lyme disease cases found that the number of reports increased, yet the percentage of positive cases after investigation decreased, which suggested that the e-reporting system facilitated overreporting.²⁷

In addition to ten articles with negative overall conclusions, five individual negative findings were included in the group of mixed-positive articles. These additional findings related to patient safety, efficiency of care, patient satisfaction, and provider satisfaction.

The negative outcomes on patient safety and provider satisfaction occurred during implementation of an inpatient computerized provider order entry system at the aforementioned Dutch academic medical center.²⁸ Although computerized provider order entry improved prescription legibility and completeness, it introduced work-flow problems that clinicians were dissatisfied with and thought might compromise safety.

In addition to the negative finding regarding costs in the “most wired” hospitals mentioned above, a negative efficiency finding was discerned in a third study by the same authors at a Dutch academic medical center that implemented a computerized provider order entry system.²⁹ Qualitative interviews found that although the implementation improved the transfer of medication-related information from physicians to nurses or pharmacists, the system did not allow transactions in both directions, and it could not account for different medication-related tasks of different disciplines, such as having a physician review a current medication list or having nurses or pharmacists verify a new prescription and dosage. To overcome these barriers, professionals reverted to traditional methods of communication.

The negative finding on patient satisfaction was observed in a US study. It reported that par-

ticipants in focus groups did not view as an advantage the ability to have secure e-mail communication with providers through the patient portal.³⁰

SINGLE-INSTITUTION STUDIES AND HEALTH IT LEADERS Goldzweig and colleagues also examined studies of leaders in health information technology.² We added the Department of Defense to their health IT leaders list, which included institutions such as Intermountain Healthcare in Salt Lake City, Utah; Partners Healthcare in Boston, Massachusetts; Regenstrief Institute in Indianapolis, Indiana; and Vanderbilt in Nashville, Tennessee. The list also included leaders at care systems including the Veterans Affairs system, the Kaiser Permanente health system, and the National Health Service in the United Kingdom, all of which have been recognized for their pioneering efforts in health information technology.

Twenty-eight articles (18 percent) included in our study came from health IT leaders, compared with thirty-six (20 percent) in the study by Goldzweig and colleagues² and sixty-four (25 percent) in the study by Chaudhry and colleagues.⁶ These studies did not differ systematically from the others in terms of overall conclusions, use of statistical methods, number of outcome measures, or number of meaningful-use criteria explicitly addressed (Exhibit 3).

More than half (98, or 64 percent) of our 154 studies addressed health IT in a single institution or tightly integrated network. Of these, twenty-eight came out of the health IT leaders discussed above: twelve from Partners Healthcare, five from Veterans Affairs, four from Kaiser Permanente, three from the UK National Health Service, two from Intermountain, and one each from Regenstrief and Vanderbilt.

Discussion

A large majority of the recent studies show measurable benefits emerging from the adoption of health information technology. However, with

EXHIBIT 3

Outcomes And Study Methods: Health Information Technology Leaders Compared To All Others

	From health IT leader	All others	p value (two-tail)
Number of studies	28	126	
Reached positive overall conclusion	19 (68%)	83 (61%)	0.25
Used statistical methods to test a hypothesis	13 (46%)	52 (41%)	0.31
Mean number of outcomes	1.64	1.52	0.20
Mean number of meaningful-use criteria	1.89	1.63	0.18

SOURCE Authors' analysis of published peer-reviewed studies.

so few negative articles and findings, there is only suggestive evidence that more advanced systems or specific health IT components facilitate greater benefits.

In fact, the stronger finding may be that the “human element” is critical to health IT implementation. The association between the assessment of provider satisfaction and negative findings is a strong one. This highlights the importance of strong leadership and staff “buy-in” if systems are to successfully manage and see benefit from health information technology.

The negative findings also highlight the need for studies that document the challenging aspects of implementing health IT more specifically and how these challenges might be addressed. Taking a cue from the literature on continuous quality improvement, every negative finding can be a treasure if it yields information on how to improve implementation strategies and design better health information technologies. Specific data on the aspects of electronic health records and other tools that physicians find most difficult to use, the training and support needed before implementation begins, and the unintended consequences of technology adoption could be fed into product development and technical assistance programs for providers.

In terms of assessing how the evidence has changed, perhaps the most important point of contrast with earlier reviews is that the newer studies are no more robust and the findings are no more positive for health IT leaders than for organizations outside that group. In other words, providers other than the large integrated care models that have led health IT adoption seem to be experiencing effects similar to those of early health IT leaders.

When considering new federal efforts designed to bring forth benefits from health IT on a broad scale, this is perhaps the most important finding. Federal funding was traditionally used to spur basic research in science, technology, and medicine. More recently, policy makers and clinicians have recognized the importance of translational research and behavioral factors in the diffusion of medical innovation. Health information technology is an arena in which new federal efforts to align payment

The “human element” is critical to health IT implementation.

with delivery system reforms can reinforce the translation of research into broad practice.

President Obama and Congress envisioned that the HITECH Act would provide benefits in the form of lower costs, better quality of care, and improved patient outcomes. This review of the recent literature on the effects of health information technology is reassuring: It indicates that the expansion of health IT in the health care system is worthwhile. Articles addressing both efficiency and effectiveness—the outcomes most in line with national goals—are more positive, and have more sophisticated study designs, than those that do not—most notably, articles addressing single outcomes or focusing on provider satisfaction. Thus, with HITECH, providers have an unparalleled opportunity to accelerate their adoption of health information technology and realize benefits for their practices, institutions, patients, and the broader system.

In addition, studies of innovative uses of health IT continue to emerge. The challenge for federal policy makers will be to monitor these developments, spur the development of new information tools, and disseminate the most promising findings more widely.

In this way, the broad base of electronic health record use fostered by the HITECH Act will be only the beginning. The Innovation Center created under the Affordable Care Act, together with the actions of private-sector health plans and providers, will be able to build on this foundation to test innovative care delivery and payment strategies. What’s more, through the broad use of health information technology, they will be able to test innovations in care delivery and payment in diverse practice settings, capture data on the effects of those strategies, and feed data back into the cycle of innovation. ■

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