

Draft Systematic Review

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Health Information Exchange

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Preface

The Agency for Healthcare Research and Quality (AHRQ), through its Evidence-based Practice Centers (EPCs), sponsors the development of systematic reviews to assist public- and private-sector organizations in their efforts to improve the quality of health care in the United States. These reviews provide comprehensive, science-based information on common, costly medical conditions, and new health care technologies and strategies.

Systematic reviews are the building blocks underlying evidence-based practice; they focus attention on the strength and limits of evidence from research studies about the effectiveness and safety of a clinical intervention. In the context of developing recommendations for practice, systematic reviews can help clarify whether assertions about the value of the intervention are based on strong evidence from clinical studies. For more information about AHRQ EPC systematic reviews, see www.effectivehealthcare.ahrq.gov/reference/purpose.cfm

AHRQ expects that these systematic reviews will be helpful to health plans, providers, purchasers, government programs, and the health care system as a whole. Transparency and stakeholder input are essential to the Effective Health Care Program. Please visit the Web site (www.effectivehealthcare.ahrq.gov) to see draft research questions and reports or to join an e-mail list to learn about new program products and opportunities for input.

We welcome comments on this systematic review. They may be sent by mail to the Task Order Officer named below at: Agency for Healthcare Research and Quality, 540 Gaither Road, Rockville, MD 20850, or by email to epc@ahrq.hhs.gov.

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Key Informants

In designing the study questions, the EPC consulted several Key Informants who represent the end-users of research. The EPC sought the Key Informant input on the priority areas for research and synthesis. Key Informants are not involved in the analysis of the evidence or the writing of the report. Therefore, in the end, study questions, design, methodological approaches, and/or conclusions do not necessarily represent the views of individual Key Informants.

Key Informants must disclose any financial conflicts of interest greater than \$10,000 and any other relevant business or professional conflicts of interest. Because of their role as end-users, individuals with potential conflicts may be retained. The TOO and the EPC work to balance, manage, or mitigate any conflicts of interest.

The list of Key Informants who participated in developing this report follows:

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Technical Expert Panel

In designing the study questions and methodology at the outset of this report, the EPC consulted several technical and content experts. Broad expertise and perspectives were sought. Divergent and conflicted opinions are common and perceived as healthy scientific discourse that results in a thoughtful, relevant systematic review. Therefore, in the end, study questions, design, methodologic approaches, and/or conclusions do not necessarily represent the views of individual technical and content experts.

Technical Experts must disclose any financial conflicts of interest greater than \$10,000 and any other relevant business or professional conflicts of interest. Because of their unique clinical or content expertise, individuals with potential conflicts may be retained. The TOO and the EPC work to balance, manage, or mitigate any potential conflicts of interest identified.

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Peer Reviewers

Prior to publication of the final evidence report, EPCs sought input from independent Peer Reviewers without financial conflicts of interest. However, the conclusions and synthesis of the scientific literature presented in this report does not necessarily represent the views of individual reviewers.

Peer Reviewers must disclose any financial conflicts of interest greater than \$10,000 and any other relevant business or professional conflicts of interest. Because of their unique clinical or content expertise, individuals with potential non-financial conflicts may be retained. The TOO and the EPC work to balance, manage, or mitigate any potential non-financial conflicts of interest identified.

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Health Information Exchange

Structured Abstract

Objectives. This review sought to systematically search and review the available literature on health information exchange (HIE), the sharing of information across the boundaries of health care organizations. HIE has been promoted as an important application of technology in medicine that can improve the efficiency, cost-effectiveness, quality, and safety of health care delivery. However, HIE also requires considerable investment by sponsors, which have included governments as well as health care organizations. This review aims to synthesize the currently available research addressing HIE effectiveness, use, usability and other barriers and facilitators to use, implementation, and sustainability, and present this information as a foundation on which future implementation, expansion, and research can be based.

Data sources. Searches designed by a reference librarian were conducted of electronic databases including MEDLINE (1990 to April 2014), PsycINFO (1990 to June 2014), the Cochrane Central Register of Controlled Trials (through May 2014), Cochrane Database of Systematic Reviews (through April 2014), the Database of Abstracts of Reviews of Effects, and the National Health Sciences Economic Evaluation Database (through the second quarter of 2014). The searches were supplemented by reviewing reference lists and the table of contents of journals not indexed in the databases we searched.

Review methods: Abstracts and the selected full-text articles were reviewed by two investigators for inclusion based on predefined criteria. Discrepancies were resolved through discussion and consensus, with a third investigator making the final decision as needed. Data was abstracted from each included article by one person and verified by another. All analyses were qualitative, and they were customized according to the topic.

Results: We included 115 studies overall, with 31 on effectiveness, 23 of which reported intermediate clinical, economic, or patient outcomes, and 9 that reported on clinical perceptions of HIE. We also found 33 studies on the use of HIE, 17 on usability and other facilitators and barriers to use of HIE, 37 on facilitators or barriers to HIE implementation, and 14 on factors related to sustainability of HIE. No studies of HIE effectiveness reported impact on direct clinical outcomes or identified harms. The majority of the included studies on effectiveness reported that HIE improved resource use by reducing lab tests, imaging, or hospital admissions by varying amounts. One study reported association of HIE participation with a higher proportion of physicians being at or above the median on clinical quality of care measures (64% vs. 49%). Studies of HIE use found that HIE adoption has increased over time, with use between 30 and 58 percent for hospitals in 2012 and 38 percent of office-based physicians in 2012, while use remains low among long-term care providers. Within organizations with HIE, the number of users or the number of visits in which the HIE was used was generally very low. The degree of usability of an HIE was associated with increased rates of use, but not with effectiveness outcomes. The most commonly cited barriers to HIE use were incomplete patient information, inefficient workflow, and poorly designed interface and update features. While several studies provided information on both external environmental and internal organizational characteristics that affect implementation and sustainability, it was not possible to assess their comparative impact on the success of HIE.

Limitations: The scope of studies identified was limited compared with the actual uses and capabilities of HIE. The outcomes measured and methods of measurement and analysis, for example, were limited and narrowly defined; the issue of potential confounders was not addressed in most studies of effectiveness, and harms were not adequately studied. There was a high degree of heterogeneity in study designs and quality, outcomes and other metrics, and HIE types and settings across the studies, limiting the ability to synthesize the evidence; no quantitative analyses were possible. The applicability of this evidence-base is uncertain because HIE systems are so diverse, and many in existence have not contributed to research in this field.

Conclusions: The full impact of HIE on clinical outcomes and potential harms is inadequately studied, although evidence provides some support for benefit in reducing use of some specific resources and achieving improvements in quality of care measures. Use of HIE has risen over time and is highest in hospitals and lowest in long-term care settings. However, use of HIE within organizations that offer it is still low. Barriers to HIE use include incomplete patient information, inefficient workflow, and poorly designed interface and update features, but factors affecting implementation and sustainability remain unclear. To advance our understanding of HIE, future studies need to address comprehensive questions, use more rigorous designs, and be part of a coordinated, systematic approach to studying HIE.

Contents

Executive Summary	ES-1
Introduction	1
Background	1
Scope of Review and Key Questions	2
Methods	6
Topic Development and Refinement	6
Literature Search Strategy	6
Process for Study Selection	7
Populations	7
Interventions and Comparators	7
Outcomes by Key Question	7
Timing	8
Settings	8
Study Design	9
Data Abstraction and Data Management	9
Assessment of Methodological Risk of Bias of Individual Studies	9
Data Synthesis and Organization of Report	10
Grading the Body of Evidence for Each Key Question	10
Assessing Applicability	11
Peer Review and Public Commentary	11
Results	12
Results of Literature Searches	12
Description of Included Studies	12
Key Question 1. Is HIE effective in improving clinical, economic, and population outcomes?	
Key Question 2. What harms have resulted from HIE?	
Key Question 3. Is HIE effective in improving intermediate outcomes such as patient and provider experience, perceptions or behavior; health care processes; or the availability, completeness, or accuracy of information?	13
Key Points	13
Detailed Synthesis	13
Key Question 4. What is the current level of use and primary uses of HIE?	24
Key Points	24
Detailed Synthesis	24
Key Question 5. How does the usability of HIE impact effectiveness or harms for individuals and organizations?	
Key Question 6. What facilitators and barriers impact use of HIE?.....	52
Key Points	52
Detailed Synthesis	52
Key Question 7. What facilitators and barriers impact implementation of HIE?	
Key Question 8. What factors influence sustainability of HIE?.....	64
Key Points	64
Detailed Synthesis	64
Discussion	72
Key Findings	72
Strength of Evidence	73

Findings in Relationship to What Is Already Known	74
Applicability	75
Limitations of the Evidence Base	76
Future Research Needs	77
Conclusions	78
References	79
Abbreviations and Acronymns	89

Tables

Table ES-1. Summary of evidence	ES-2
Table 1. Studies of HIE included for assessing outcomes	15
Table 2. Patient and clinician perceptions of HIE	22
Table 3. Factors that may affect outcomes	23
Table 4. Level of use and primary uses of HIE, participation in health information exchanges, types of data exchanged, characteristics of successfully participating organizations, U.S. wide studies	28
Table 5. Level of use and primary uses of HIE, transfer of records between integrated delivery systems	35
Table 6. Level of use and primary uses of HIE, participation in HIEs, extent of use, by regional or statewide initiatives	39
Table 7. Level of use and primary uses of HIE, extent of use, types of information exchanges, and adoption, in international or multi-national settings	50
Table 8. Barriers and facilitators of actual HIE use grouped by theme	55
Table 9. Summary of evidence addressing usability, barriers, and facilitators to use	59
Table 10. Facilitators to implementation and sustainability of HIE	70
Table 11. Barriers to implementation and sustainability of HIE	71
Table 12. Summary of evidence	72

Figures

Figure 1. Analytic framework	3
Figure 2. Literature flow diagram	12
Figure 3. Opposing forces of barriers and facilitators to the use of HIE reported in more than one study	56

Appendixes

Appendix A. Search Strategies
Appendix B. Inclusion and Exclusion Criteria
Appendix C. List of Included Studies
Appendix D. List of Excluded Studies
Appendix E. Risk of Bias Assessment Criteria
Appendix F. Strength of Evidence Criteria
Appendix G. Evidence Table
Appendix H. Quality Assessment Tables

Executive Summary

Background

Health information exchange (HIE) is the sharing of electronic clinical data across organizations. The idea that records should follow patients wherever they receive care has been promoted as a cornerstone of efforts to improve the coordination, efficiency, and effectiveness of health services. The underlying belief is that ultimately patients would benefit if all relevant information were available to the various health care providers involved in treating them and working to maintain their health. However, realizing this vision is challenging because health care is currently provided by a diversity of organizations and providers with disparate information systems. A substantial investment of resources is needed to develop an environment that allows health care information to follow the patient.

Governments at all levels, as well as health systems and individual organizations, have and are continuing to make the investment of time and resources to achieve the goals of HIE. For example, in the United States, the Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the American Recovery and Reinvestment Act of 2009, is providing up to \$29 billion in incentive funding for the adoption and “meaningful use” of electronic health records (EHRs) by hospitals and health professionals. The HITECH Act designated an additional \$564 million for investment in state-level HIE. Understandably, all stakeholders are interested in assuring that there is a return on this investment

The purpose of this review was to identify, summarize, and synthesize the available research about HIE. The scope of the review was purposely broad and includes studies about four topics: 1) effectiveness, 2) use of HIE, 3) usability and other barriers and facilitators to use, and 4) implementation and sustainability.

Methods

This review was completed by the Pacific Northwest Evidence-based Practice Center in fulfillment of a contract from the Agency for Healthcare Research and Quality (AHRQ) through the Effective Health Care Program. We used the Program’s standard methods and procedures,¹ which are similar to those established by the Institute of Medicine for systematic reviews.² A detailed description of the methods is available in the review protocol and in the full report, both available at www.effectivehealthcare.ahrq.gov.

After finalizing the Key Questions to be considered in our review, we looked for reports of HIE research. We searched several bibliographic citation databases (e.g., MEDLINE) with support from a specialized reference librarian, and we searched web sites and tables of contents of publications that are not indexed in citation databases. The retrieved abstracts were reviewed by investigators, and the full text of articles were pulled and reviewed if at least one investigator felt the study met our inclusion criteria. We included any study with data about an actual HIE designed to be used for clinical or public health decisionmaking. We included many different types of studies in order to provide a comprehensive review of research on HIE effectiveness, use, usability, implementation, and sustainability. Given this broad scope, the included studies vary widely in design and quality. We did not include studies of exchanges of data for research only or studies about hypothetical, future HIEs. Data from included studies were abstracted from the articles and this information was summarized in tables and narratives.

Results

Overview

We grouped our original eight Key Questions into four topic areas in order to more cohesively present our findings. The major results are summarized in **Table ES-1** and described below.

Table ES-1. Summary of evidence

Topic Number of included Studies Type	Main Findings	Primary Limitations of the Evidence
Effectiveness 31; 29 retrospective cohort; 2 RCTs	Most studies reported positive findings but the strength of evidence was low for all outcomes.	Studies are of a small number of the functioning HIEs, with similarity to unstudied ones unknown. Possibly limited generalizability. Studies look at extremely limited outcomes considering the intended scope of the impact of HIE
Use 51; 20 Surveys 13 Audit Logs 9 Retrospective database 5 Mixed methods 2 Focus Groups 1 Time-motion 1 Geo-Coding	Proportion of hospitals and ambulatory care practices that have adopted HIE is increasing. Currently, rates of use within organizations with HIE are generally low.	While there are relatively high quality national and regional surveys and reports that track the expansion of HIE among health care organizations, there is not a corresponding comprehensive effort to track changes in rates of use within organizations.
Usability and other factors affecting use 17; 13 Qualitative 4 Mixed methods	Most commonly cited barriers to HIE use were: incomplete patient information (8 studies); inefficient workflow (6 studies); poorly designed interface and update features (6 studies).	Studies of usability did not relate it to effectiveness and do not permit comparisons across settings or types of HIE Studies had limitations such as incomplete reporting on sampling, low response rates, or selection of a narrow setting or patient population, which minimize applicability.
Implementation and sustainability 45; 13 Interviews 11 Qualitative analysis of several data sources 5 Mixed methods 16 Quantitative	Most facilitators of implementation are characteristics of the HIE or the internal organizational environment. Many barriers to implementation are external, environmental factors. Factors related to sustainability overlap with those identified for implementation.	Studies do not allow comparison of the impact of different barrier and facilitators. The definition and appropriate measures of sustainability are not yet clear.

We reviewed 4,809 abstracts and 616 full-text articles. Of these we included 115 studies that addressed one or more of our Key Questions. The data in the following section comes from studies of 12 different HIEs that represent a small proportion of the HIEs that function in the United States, a few national surveys/data sets, and a small number of studies in other countries. Most of this literature has been published since 2006. Most studies were retrospective cohorts (analysis of existing data comparing a certain outcome with and without HIE) or qualitative analysis of responses from interviews, questionnaires, or focus groups. Other research designs represented included pre/post or time series studies, which looked at what happened before and

after HIE implementation, or mixed methods case studies. There were only two randomized trials identified. In general, the risk of bias for these studies was high (high risk of bias means we do not place much confidence in the reported results), with some rated as moderate, though not all study designs were rated, and the strength of evidence was assessed as low or insufficient.

Effectiveness

We identified 31 studies that linked HIE to outcomes, with 23 assessing the impact of HIE on resource use and 9 reporting on user perceptions of HIE impact or data quality issues. Studies that examined whether HIE improved resource use defined this as 1) reduced hospital admissions, readmissions, consultations, emergency department (ED) costs, lab tests, and radiology exams, 2) successful public health use, or 3) improvement in quality of care or service delivery. The overall strength of evidence is low, as most studies were retrospective and answered questions in very limited ways.

The studies of admissions and readmissions had inconsistent findings with some reporting that HIE reduced admissions³⁻⁶ or readmissions,⁷ while others reported no effect.⁸⁻¹¹ Similarly, the findings related to consultations or referrals were mixed, with one study reporting few consultations and cost savings⁵ and another reporting an increase in referrals by both primary care physicians and specialists.¹²

In contrast, studies of other resource use outcomes more consistently identified benefits. Two studies found that HIE reduced overall emergency costs.^{4,13} Four U.S. studies found reductions in both lab tests and radiology exams,^{4,5,13,14} and three in radiology alone,¹⁵⁻¹⁷ while one study in Finland found that orders for lab tests increased.¹² Studies of quality of care found that physicians providing preventive services and using an HIE portal performed better on quality measures,^{18,19} and that an HIE could help identify frequent ED users and medication adherence problems,²⁰ though medication adherence did not improve during the study.²¹ One study found that HIE reduced the time needed to evaluate Social Security claims.²²

In studies that asked users of HIE to report on their perception of its impact, all found some benefit, though they were not universal. Physicians were more satisfied with electronic than paper lab reports;²³ more physicians liked HIEs that pushed data to them than HIEs that required them to pull the data with a query;²⁴ physicians believe electronic reports of ED use improved followup;^{25,26} and HIE improved ambulatory care function.^{27,28} However, physicians in one study responded that an HIE providing pharmacy information in the ED improved knowledge but did not reduce time spent to provide service and was not worth the cost.²⁹ The one included study of patient satisfaction reported that patients preferred records transferred via HIE over transferring paper records themselves.³⁰

Although most studies of the effectiveness of HIE reported positive results, the literature as a whole was not comprehensive and few studies were of high quality. HIE is usually a broad-based system designed to affect practice and numerous outcomes; however, evaluation studies have focused on only one or a small number of uses or potential effects. Additionally, even in cases where the results were positive, the effect sizes were not large or able to be assessed given the information provided (e.g., ED savings are hard to evaluate if the overall budget for the ED is not known). Additionally, many studies have employed simple study designs that do not allow for risk of bias assessment (thus lowering our confidence in the study results). Given these limitations it is not possible to conclude with any certainty that HIE is effective as an intervention to improve health outcomes.

Use of Health Information Exchange

We identified 51 studies that described either the level of use of HIE or the primary uses of HIE. Of these, 13 studies evaluated HIE use nationally in the United States, and two studies evaluated HIE use across integrated delivery systems. The majority (29 studies) of these studies analyzed the extent to which HIE was implemented in a state or across a region, but these were concentrated in New York (9 studies), Texas (5 studies), and Tennessee (5 studies). Four studies evaluated HIE in other countries and one in multiple countries including the United States.

Nationwide surveys in the United States suggest that HIE use has risen substantially among hospitals in the last 5 years. Hospital use of HIE was reported by 11 percent of hospitals in 2009,³¹ while more current estimates range from 30 to 58 percent.³²⁻³⁴ In ambulatory care settings, results from the National Ambulatory Medical Care Survey (2013) concluded that 39 percent of office-based physicians reported having an HIE with other providers or hospitals.³⁵ Limited data suggest that use of technology in general and HIE specifically is very low in long-term care settings.³⁶

All regional health information exchanges (RHIOs) are involved in HIE by definition, but both their reach and composition vary. In 2008 and 2009, RHIOs included 14 percent of U.S. hospitals and 3 percent of ambulatory care practices.³⁷ A study of public health departments and RHIOs found that 36 percent had no RHIO in their jurisdiction and 12 percent had no relationship with the RHIO in their area.³⁸ Of those with a RHIO in their area, 40 percent were actually exchanging information.³⁸ In RHIOs, the entities most commonly providing data are hospitals (83%), followed by ambulatory settings (60%); the entities most commonly receiving data were ambulatory settings (95%), followed by hospitals (83%), public health departments (50%), and payers (44%).³⁹

Studies of HIE in integrated delivery systems included exchanges among the Department of Defense, Department of Veterans Affairs (VA), and the private sector. In an initial test in one city, 73 percent of patients could be located across the system and exchanges were executed two to three times a week.⁴⁰ A larger 12-site expansion experiment resolved some issues in matching patients but reported that the VA received information from private organizations for 9 percent of the matched patients.⁴¹

While organizational involvement and capacity for HIE are increasing, the data about actual use of HIE when it is available is limited and suggest that HIE is still not integrated into usual care. For example, studies from the MidSouth e-Health Alliance suggest low use of HIE overall (between 2.6% and 9.5% of visits in 2008 and 2009)⁴² with higher use for ED visits (15%) and return clinic visits (19%).⁴³ In another example, data collected in the Central Texas HIE between 2006 and 2011, HIE use was low—used in only 2.3 percent of encounters.⁴⁴

Usability and Other Barriers and Facilitators to Use

We reviewed 17 studies that examined either usability or other barriers and facilitators to use of 11 different HIEs.

Four surveys of HIE users found that usability features were related to actual use, with one study reporting higher scores on a measure of satisfaction with user interface related to more frequent use,⁴⁵ while another reported that users endorsing statements that the HIE was easy to learn to operate and useful had higher levels of weekly HIE use.⁴⁶ Providers who used HIE also reported increased satisfaction, improved relationships with care partners,⁴⁷ and perceptions that care was more integrated.⁴⁸ A related negative finding was that providers had high expectations

for HIE before implementation and reported some ongoing unmet needs once HIE was operational.⁴⁷

Barriers and facilitators to use of HIE were identified using qualitative analyses of interviews and case studies that drew on data from several sources (e.g., interviews, focus groups, and observations). Barriers and facilitators identified fell under three broad topics: completeness of data, workflow, and interface.

Completeness of data is a key issue—if providers do not find useful data from HIE they are less likely to use HIE in the future. Data were incomplete due to issues with the setting (more complete in an ED and less in a homeless center) or due to challenges in matching patients across systems.⁴⁹ Privacy, legal concerns, and requirements that patients opt-in or opt-out to sharing data all reduce the completeness of data, and approaches to address these factors can lead to more comprehensive data and increased use.⁴⁷ Differences in how HIEs were incorporated into workflow and daily operations also affected use. Studies found that when proxy, nonphysician users accessed the system and provided relevant information to the doctors, the system was used more frequently.^{42,43} Studies based on observations found that different providers used the HIE differently, with nurses seeking information on hospitals or other care mentioned by the patients, while physicians also used HIE to complete their understanding of the patient history and to facilitate decisionmaking.⁵⁰ The interface and features of the HIE systems were also cited as encouraging or hindering use. User opinions differed in terms of whether they wanted more or less information, based both on desire for more content⁵¹ and on interface issues, such as the need to scroll or click through multiple pages.^{46,52,53} In addition, users reported that as HIEs expanded the systems slowed down,⁴¹ or that new information was not added to centralized systems quickly enough (such that going to records in separate systems was quicker).⁴⁶

While large, expensive HIE systems are designed based on human factors as well as on data interoperability, the human component still seems to present challenges to be resolved. HIEs need to facilitate the exchange of data in a way that can be integrated into the workflow and that better accommodates users' needs and expectations.

Implementation and Sustainability

We found 45 studies that aimed to identify factors that affect implementation and sustainability. Thirty-seven studies identified facilitators to implementation (which we grouped into eight categories) and barriers (which we grouped into seven categories). While fewer studies (14 studies) considered sustainability, we sorted the positive and negative influences so that they overlapped with our categories of facilitators and barriers to implementation. Studies did not provide enough data to allow us to assess the comparative impact of different factors on implementation and sustainability.

Facilitators for implementation focused predominately on the characteristics of the implementing organization or of the HIE they were planning to implement. General structural characteristics included leadership^{22,54-56} and prior experience with or readiness for information technology (IT) projects.^{47,57} HIE specific structures that helped with implementation included governance²² and participatory approaches.^{19,58,59} Organizations implementing HIE shifted their mission or focus toward collaboration⁶⁰ and continuity of care.⁶¹ They also provided support for the implementation, such as training,^{62,63} and they focused on selected outcomes, such as meeting a community need.⁶⁴ HIE designs that reflected workflow⁵⁹ and included functions that could be integrated into care processes^{41,63,65,66} were also considered facilitators for implementation. The

one type of external factor cited as a facilitator was policy in the form of Federal and State laws and mandates,^{65,67} as well as grants.⁵⁷

Barriers to implementation identified in the research literature overlapped with facilitators but included more categories of external factors. Laws and grants were identified as a barrier when their timelines or changes in requirements imposed a burden on organizations.^{55,68} The most frequently cited barrier was disincentives, including the issue of financial viability^{57,62,65,69,70} and the mismatch between those who invest in HIE and those who benefit.^{57,71,72} The characteristics of the technological environment that hindered implementation included lack of standards^{38,73} and limited interoperability across organizations.^{65,74,75} Three categories of barriers were related to the organization and its HIE efforts. These included the lack of necessary components, such as physician engagement,⁶⁰ the fit between the goals and timeline of the organization and HIE efforts,^{76,77} and problems with user interface and functionality.⁴¹

Fewer studies considered sustainability. Positive influences included factors identified as associated with sustainability, such as leadership by a health information organization⁷⁸ and provision of direct financial benefit to HIE participants.^{71,79} The most commonly cited negative influences were competition and the difficulty in making the business case for HIE.⁸⁰⁻⁸³ Other hindrances to sustainability identified were structural factors, such as a mismatch between the geographic coverage of the HIE and the service area,⁸³ governance issues and lack of trust,^{83,84} and lack of engagement of participating organizations and their providers.⁶⁴

Implications

HIE represents a significant component of health care reform efforts. HIE is one of the major applications of health IT and requires significant resources. Thus it is not surprising that numerous studies have been published about HIE. However, this body of literature is limited in several ways. Most of the studies are not designed to sufficiently control for risk of bias and they focus on relatively narrow outcomes when assessing the impact of a broad-based systemic intervention such as HIE. Additionally the studies of use, usability, implementation, and sustainability provide information on context and allow some insight into trends but in general do not permit any comparative assessment or ranking of the importance of different barriers or facilitators.

Although it may not be the purview of research to decide if HIE should be funded as infrastructure (like a utility) or as a part of business operations, the overriding consensus that HIE should improve efficiency and quality of care is not overwhelmingly supported by the available evidence. Positive findings are encouraging, but both the level of the impact and some inconsistencies in results preclude any definitive conclusion.

Additionally, while surveys suggest use of HIE is spreading, the scope of use within organizations is still limited, implementation is slow, and sustainability seems less than assured. Exactly what is needed for HIE to be effective is also difficult to discern from a body of literature that does not include many comparative studies and that does not seem to build on prior results to create a succession of increasingly relevant studies.

Despite these concerns, expansion of HIE seems likely, and research could better serve this effort by developing and pursuing a more deliberate research agenda designed to capture the full (potential) impact of HIE and identify the comparative role of specific factors related to use, usability, implementation, and, ultimately, sustainability.

Conclusions

The full impact of HIE on clinical outcomes and potential harms is inadequately studied, although evidence provides some support for benefit in reducing use of some specific resources and improving quality of care measures. Use of HIE has risen over time and is highest in hospitals and lowest in long-term care settings. However, use of HIE within organizations that offer it is still low. Barriers to HIE use include incomplete patient information, inefficient workflow, and poorly designed interface and update features, but factors affecting implementation and sustainability remain unclear. To advance our understanding of HIE, future studies need to address comprehensive questions, use more rigorous designs, and be part of a coordinated, systematic approach to studying HIE. To advance our understanding of HIE, future studies need to address comprehensive questions, use more rigorous designs, and be part of a coordinated, systematic approach to studying HIE.

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Introduction

Background

The use of health information technology (IT) has the potential to improve the quality, safety, and efficiency of health care in the United States.¹ Health IT can support patient care related activities such as communications, results reporting, order entry, care planning, and documentation. Examples of health IT applications include the electronic health record (EHR), clinical decision support such as alerts and reminders, computerized provider order entry, electronic access to clinical practice guidelines and evidence databases, consumer health informatics applications, telemedicine, and electronic exchange of health information.

In recent years, the Health Information Technology for Economic and Clinical Health (HITECH) Act has accelerated adoption of the EHR in ambulatory and hospital settings across the United States. The HITECH Act, part of the American Recovery and Reinvestment Act of 2009, is providing up to \$29 billion in incentive funding for the adoption and “meaningful use” of EHRs by hospitals and physicians. As a result of HITECH funding, 94 percent of non-federal U.S. hospitals,² 78 percent of U.S. hospital-based physicians,³ 84 percent of hospital emergency departments, and 73 percent of hospital outpatient departments have adopted EHRs.⁴ The motivation to increase the use of health IT is grounded in evidence that health IT may improve the quality, safety, efficiency, and satisfaction with health care, as has been reported in recent systematic reviews.⁵⁻⁸

A key challenge to effective use of health IT, however, is that most Americans, especially those with multiple illnesses, receive care in multiple settings. In Massachusetts, out of 3.7 million patients hospitalized, 31 percent visited two or more hospitals over 5 years (57% of all visits) and 1 percent visited five or more hospitals (10% of all visits).⁹ Similarly, an analysis of 2.8 million emergency department patients in Indiana found that 40 percent had data at multiple institutions.¹⁰ This presents a challenge if we are to meet the goal stated by former Agency for Healthcare Research and Quality (AHRQ) Director Dr. Carolyn Clancy that, “data should follow the patient” wherever they get their care.¹¹

To enable data to follow patients wherever they receive care, increased attention has been paid to health information exchange (HIE), which has been defined as the reliable and interoperable electronic sharing of clinical information among physicians, nurses, pharmacists, other health care providers and patients across the boundaries of health care institutions, health data repositories, states and other entities who are not within a single organization or among affiliated providers.¹² The HITECH Act recognized that EHR adoption alone would not be sufficient to achieve the full value of health IT, allocating another \$563 million for state-based HIE.¹³ In the meantime, a growing number of private organizations have undertaken HIE.¹⁴ Ideally, HIE across provider organizations should help coordinate care transitions between settings, improve patient safety, and reduce unnecessary duplicate testing.

The Office of the National Coordinator for Health IT (ONC) has defined three key forms of HIE:¹³

- Directed exchange: sending and receiving of secure information electronically between care providers

- Query-based exchange: provider-initiated requests for information on a patient from other providers
- Consumer-mediated exchange: patients aggregating and controlling the use of their health information among care providers

An early successful example of HIE was the work of Dr. Clement McDonald, who pioneered HIE in Indiana starting in the 1990s.¹⁵ This work led to the formation of the Indiana Health Information Exchange, one of the largest and most successful HIE efforts in the United States.¹⁶ Other early programs aiming to achieve HIE, including some high-profile efforts, were less successful.¹⁷ Although the rationale for HIE is critically important,¹⁸ the path to achieving it has been more difficult than the adoption of EHRs,^{19,20} in part due to the lack of sustainable business models.^{21,22}

Another major barrier to HIE has been the adoption of health IT standards to ensure interoperability among systems. This has led ONC, the lead government agency for health IT development, to prioritize interoperability in its most recent strategic plan for health IT in the United States.²³ ONC has launched a process to establish an interoperability roadmap that will guide implementation of standards and interoperability, which also has the potential to facilitate adoption and improvement of HIE.²⁴

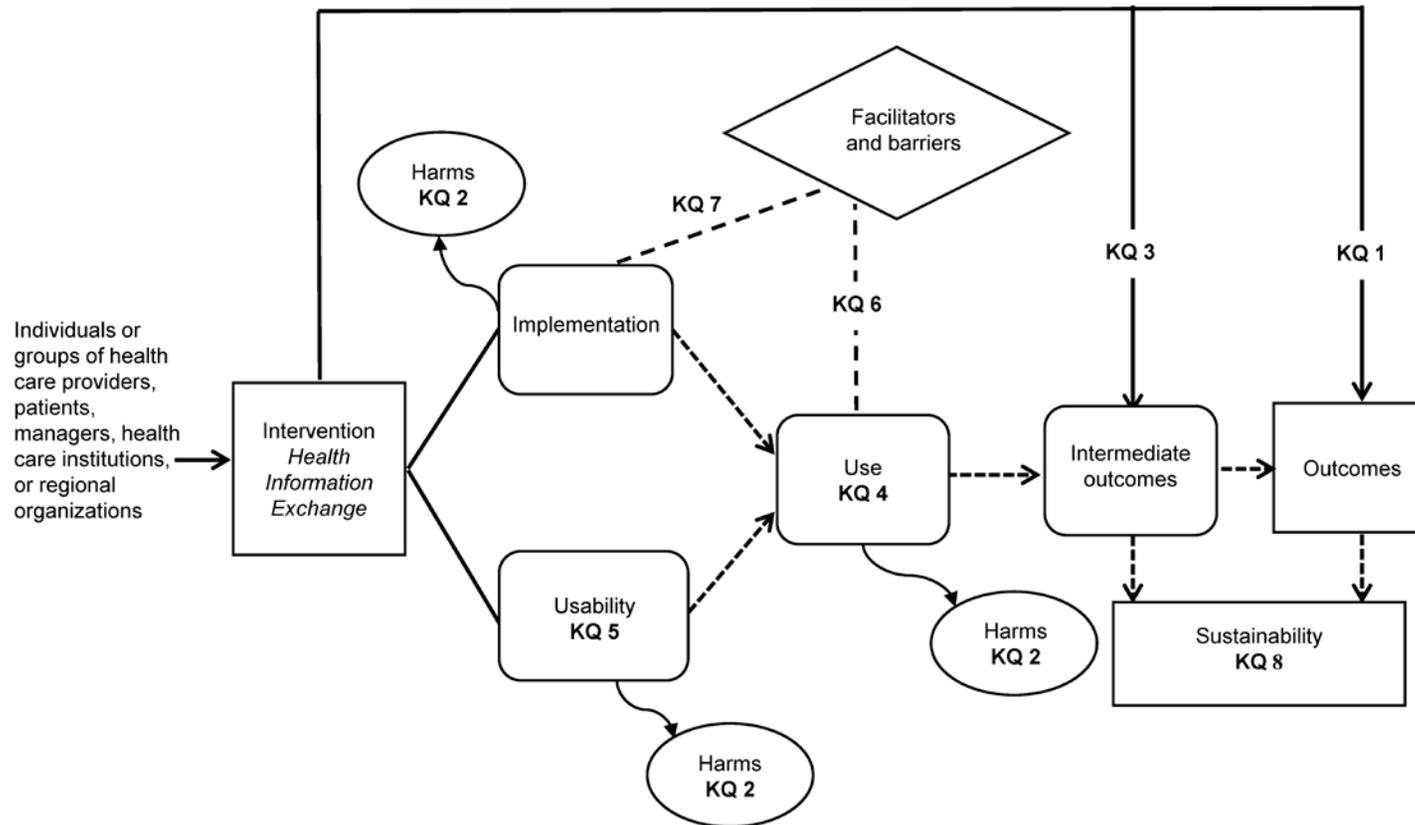
Evaluating the effectiveness of HIE is also challenging. HIE is an intermediate technology designed to improve health care delivery overall, but is not specific to any disease. HIE implementations have often been supported by one-time start-up funding, without longer-term support to sustain the programs long enough for evaluation. This is borne out in a recently published systematic review of HIE evaluations.²⁵

The promise for HIE to improve health care delivery is substantial, but adoption has been complex and costly. It is therefore critical to be able to determine if HIE does improve health or intermediate outcomes as well as to systematically assess comparative approaches, barriers, return on investment, and sustainability of HIE.

Scope of Review and Key Questions

The review undertaken is timely and necessary—our knowledge of and experience with the HIE literature indicated that the evidence base is scattered across disciplines and in various formats with only two previously published systematic reviews that focused exclusively on HIE.^{25,26} Meanwhile, AHRQ has funded a large portfolio of research in health IT and HIE,²⁷ and has also published an extensive guide to evaluating HIE projects.²⁸ In requesting this review, AHRQ's goal is a report that will focus on systematically identifying and synthesizing evidence on the extent to which HIE is effective in improving a variety of outcomes and determine if it is possible to say how the impact varies by different approaches to HIE. The report also aimed to identify evidence on levels of use, and usability of HIE, as well as facilitators of and barriers to implementation, use, and sustainability of HIE. The analytic framework (**Figure 1**) and Key Questions used to guide this review are shown below. The analytic framework shows the target populations, interventions, and health outcomes examined, with numbers corresponding to the Key Questions.

Figure 1. Analytic framework



Abbreviations: KQ= key question.

This report focuses on the following Key Questions:

Key Question 1. Is HIE effective in improving **clinical** (e.g., mortality and morbidity), **economic** (e.g., costs and resource use, the value proposition for HIE) and **population** (e.g., syndromic surveillance) **outcomes**?

Key Question 1a. Does effectiveness vary by type of HIE?

Key Question 1b. Does effectiveness vary by health care settings and systems?

Key Question 1c. Does effectiveness vary by IT system characteristics?

Key Question 1d. What evidence exists that the lack of HIE leads to poorer outcomes?

Key Question 2. What **harms** have resulted from HIE? (e.g., violations of privacy, errors in diagnosis or treatment from too much, too little or inaccurate information, or patient or provider concerns about HIE)?

Key Question 2a. Do harms vary by type of HIE?

Key Question 2b. Do harms vary by health care settings and systems?

Key Question 2c. Do harms vary by the IT system characteristics?

Key Question 3. Is HIE effective in improving **intermediate outcomes** such as patient and provider experience, perceptions or behavior; health care processes; or the availability, completeness, or accuracy of information?

Key Question 3a. Does effectiveness in improving intermediate outcomes vary by type of HIE?

Key Question 3b. Does effectiveness in improving intermediate outcomes vary by health care settings and systems?

Key Question 3c. Does effectiveness in improving intermediate outcomes vary by IT system characteristics?

Key Question 3d. What evidence exists that the lack of HIE leads to poorer intermediate outcomes?

Key Question 4. What is the current **level of use and primary uses** of HIE?

Key Question 4a. Do level of use and primary uses vary by type of HIE?

Key Question 4b. Do level of use and primary uses vary by health care settings and systems, or provider type?

Key Question 4c. Do level of use and primary uses vary by IT system characteristics?

Key Question 4d. Do level of use and primary uses vary by data source?

Key Question 5. How does the **usability** of HIE impact effectiveness or harms for individuals and organizations?

Key Question 5a. How usable are various types of HIE?

Key Question 5b. What specific usability factors impact the effectiveness or harms from HIE?

Key Question 5c. How does usability vary by health care settings or systems?

Key Question 6. What facilitators and barriers impact **use** of HIE?

Key Question 6a. Do facilitators and barriers that impact use vary by type of HIE?

Key Question 6b. Do facilitators and barriers that impact use vary by health care settings and systems?

Key Question 6c. Do facilitators and barriers that impact use vary by IT system characteristics?

Key Question 7. What facilitators and barriers impact **implementation** of HIE?

Key Question 7a. Do facilitators and barriers that impact implementation vary by type of HIE?

Key Question 7b. Do facilitators and barriers that impact implementation vary by health care settings and systems?

Key Question 7c. Do facilitators and barriers that impact implementation vary by IT system characteristics?

Key Question 8. What factors influence **sustainability** of HIE?

Methods

This systematic review follows the methods of the Agency for Healthcare Research and Quality (AHRQ) *Methods Guide for Effectiveness and Comparative Effectiveness Reviews*.²⁹

Topic Development and Refinement

The initial Key Questions were provided by AHRQ, who requested the review as part of its effort to assess the impact of the AHRQ's Health information technology (IT) Portfolio and set future direction for the field. The Key Questions and scope were further developed with input from a group of stakeholders (Key Informants) convened for this report to provide diverse stakeholder perspectives and content and methodological expertise. The Key Informants consisted of experts in health IT, applied informatics, clinical care, and health policy, as well as those representing the patient perspective. Key Informants disclosed financial and other conflicts of interest prior to participation. The AHRQ Task Order Officer and the investigators reviewed the disclosures and determined that the Key Informants had no conflicts of interest that precluded participation.

AHRQ, with input from a Technical Expert Panel (TEP) convened for this report, further developed the approach to the review. The TEP added expertise in informatics research and systematic reviews to the perspectives that were represented by the Key Informants. The protocol was then posted for public comment from February 6 to February 26, 2014. Based on public comments, we further revised the Key Questions and scope. The final protocol was developed and posted on the AHRQ web site on July 21, 2014 at:

<http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/?productid=1943&pageaction=displayproduct>. The protocol was also registered in the PROSPERO international database of prospectively registered systematic reviews. (http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42014013285#.VK8T2S S0sg)

Literature Search Strategy

A research librarian conducted searches in Ovid MEDLINE (1990 to April 2014), PsycINFO (1990 to June 2014), the Cochrane Central Register of Controlled Trials (through May 2014), Cochrane Database of Systematic Reviews (through April 2014), the Database of Abstracts of Reviews of Effects, and the National Health Sciences Economic Evaluation Database (through the second quarter of 2014). See **Appendix A** for the search strategies. Searches were peer reviewed by another librarian with experience with systematic reviews who offered suggestions and confirmed accuracy. Searches were designed to retrieve publications from January 1, 1990 forward, which reflects the timing of initial implementations of health information exchange (HIE) in the United States. During our literature scan we screened a sample of citations from two additional databases: Business Premier and Institute of Electrical and Electronics Engineers, but since neither screen resulted in identification of relevant articles the databases were not searched further for this systematic review. Literature searches will be updated prior to finalization of this report. Searches were supplemented with hand searches of reference lists of relevant studies and the table of contents of journals not indexed in the databases searched (e.g., *Generating Evidence*

and Methods to improve patient outcomes [eGEMs]), as well as searches of gray literature sources (e.g., reports and analyses on Web sites of key organizations).

In addition, Scientific Information Packets (SIPs) were requested from organizations likely to have data on research or evaluations of HIE that have not been published or indexed in citation databases. They had the opportunity to submit data using the portal for submitting SIPs on the Effective Health Care Program Web site. One submission was received from the California HealthCare Foundation.

Process for Study Selection

The criteria for inclusion and exclusion of studies was based on the Key Questions and the populations, interventions, comparators, outcomes, timing, types of studies, and setting (PICOTS) approach (**Appendix B**). Papers were selected for review if they reported data about HIE (defined below), had data relevant to a Key Question, and met the prespecified inclusion criteria. Studies of nonhuman subjects and studies with no original data were excluded. Abstracts were reviewed by two investigators for inclusion for each Key Question. Full-text articles were obtained for all studies that any investigator identified as potentially meeting inclusion criteria. Two investigators independently reviewed all full-text articles for final inclusion. Inclusion was restricted to English-language articles. A list of the included studies appears in **Appendix C**; a list of excluded studies and primary reasons for exclusion can be found in **Appendix D**. Discrepancies were resolved through discussion and consensus, with a third investigator making the final decision if necessary.

Populations

Any individual or group of health care providers, patients, managers, health care institutions, or regional organizations.

Intervention and Comparators

HIE is defined as the electronic sharing of clinical information among users such as health care providers, patients, administrators or policymakers across the boundaries of health care institutions, health data repositories, States and others, typically not within a single organization or among affiliated providers, while protecting the integrity, privacy, and security of the information.

Comparators included were time period prior to HIE implementation, different locations (geographic or organizational without HIE) or situations in which HIE is not available (akin to “usual care” in a clinical study), comparisons across types of HIE, and comparisons of the characteristics of the different settings, health care system, and IT systems in which HIE is used.

Outcomes by Key Question

Key Question 1: Effectiveness is defined in terms of clinical outcomes (e.g., mortality and morbidity), economic outcomes (e.g., costs and resource use, the value proposition for HIE) and population outcomes (e.g., syndromic surveillance for the identification of trends or clusters). Each study was assessed for its type of outcome and results in terms of the following attributes:

- Location – geographic
- Health care setting – e.g., emergency department, outpatient, health system
- HIE type – query versus directed
- Outcome category
- Direction of result – benefit versus mixed versus none

Key Question 2: Harms include unintended negative consequence or adverse events experienced by individuals, institutions, or organizations. Harms from HIE may include negative outcomes or the risk of negative outcomes resulting from information that is wrong, not provided in a timely manner, or in formats that inhibit its identification, comprehension, and use. Harms also may result from too much information as well as lack of information. Harms can also include negative impacts on attitudes (e.g., patients not trusting that privacy will be protected, clinicians’ concerns about legal liability).

Key Question 3: Intermediate outcomes include outcomes such as provider and patient experience and perceptions; changes in provider behavior and health care processes; and changes in the availability, completeness, or accuracy of information.

Key Question 4: Level of use is the rate of HIE use by individuals, health care institutions, or regional organizations.

Key Question 5: Usability focuses on the function of the HIE in terms of the interaction between users and HIE and their ability to navigate and accomplish tasks.

Key Question 6: Facilitators and barriers to the use of HIE in the workflow and decisions of patients, providers or organizations.

Key Question 7: Implementation of HIE is defined as the realization of an HIE project such that the exchange of data is operational.

Key Question 8: Sustainability is long-term maintenance, and improvement or expansion of HIE, after the implementation period.

Timing

No prespecified minimum duration of time was required between implementation of HIE to the measurement of outcomes.

Settings

Any aspect of the setting in which health information is exchanged for the purpose of improving health or health care decisions that is hypothesized to impact effectiveness, use, usability, or sustainability. This may include the type(s) of clinical environments (e.g., ambulatory care, hospital, nursing home), payment/reimbursement model(s) (e.g., fee-for-service, managed care setting, risk/value-based model such as an accountable care organization), and legislative requirements (e.g., participation in HIE required to participate in Medicaid). We

included studies using HIE in public health organizations and settings but excluded those using HIE data for clinical research.

Study Design

For questions on efficacy, effectiveness, and harms a “best evidence” approach was used. Randomized controlled trials (RCTs) were included as the top-tier evidence. If insufficient evidence was found of this type, we explored observational study evidence (defined as cohort studies comparing at least two HIE systems, case-control studies, and time-series studies).

For questions on use, usability, implementation, and sustainability, observational studies and qualitative research were included. We also included detailed case studies of single or multiple HIEs or sites.

At a minimum, systematic reviews were considered as sources of studies to be reviewed for possible inclusion. High quality reviews with information directly relevant to our Key Questions were eligible for inclusion in the review as evidence. High-quality reviews were defined as those assessed as being at low risk of bias, according to the Assessing the Methodological Quality of Systematic Reviews-AMSTAR quality assessment tool.^{29,30}

We excluded studies that model the potential impact of HIE or that present, discuss, or evaluate hypothetical situations about HIE that has not yet been implemented. We excluded descriptive narrative or “lessons learned” essays that were not based on collecting clinical, survey, or interview data from users or stakeholders. We restricted inclusion to English-language articles, but reviewed English language abstracts of non-English language articles to identify studies that would otherwise meet inclusion criteria.

Data Abstraction and Data Management

After studies were selected for inclusion, data were abstracted into categories including but not limited to: a) general information such as study design, year, setting, geographic location, and duration; b) characteristics of the HIE such as the form (directed exchange, query-based exchange, consumer-mediated exchange), the number and types of participating organizations, the type of user interface (e.g., push versus pull), and the types of information included; and c) key contextual information to be used to identify facilitators and barriers to HIE use as well as to assess applicability of the results. At a minimum, we included details about the type(s) of clinical environments (e.g., ambulatory care, hospital, nursing home), payment/reimbursement model(s) (e.g., fee-for-service, managed care setting, risk/value-based model such as an accountable care organization).

Assessment of Methodological Risk of Bias of Individual Studies

Our assessment of risk of bias of trials and observational studies was based on the recommendations in the AHRQ Methods Guide for Effectiveness and Comparative Effectiveness Reviews.²⁹ Risk of bias assessments of all studies were made by two raters. Differences were resolved by discussion and involvement of a third rater as needed. Individual studies were rated

as “low,” “moderate,” or “high” risk of bias. The criteria and interpretation of these ratings are described in our protocol and in **Appendix E**.

For studies of surveys, interviews, and focus groups we did not give a formal overall risk of bias rating; however, we did record information about sampling, completion rates, the development of the questions, and the appropriateness of the analysis. This information was used to inform our descriptions of the studies and our assessment of both the strength of evidence and the specific needs for future research. **Appendix E** also includes a list of the information we recorded. We did not assess the risk of bias of case studies, mixed methods studies, or studies based on computer system logs.

Data Synthesis and Organization of Report

We constructed evidence tables identifying the study characteristics, results of interest, and risk of bias assessment for all included studies and summary tables to highlight the main findings. For all studies, we recorded the type of HIE when described, information on the sample and response rate when reported, and types of stakeholders. We reviewed and highlighted studies by using a hierarchy of evidence approach, where the best evidence was the focus of our synthesis for each Key Question.

We present the evidence for Key Questions 1, 2, and 3 together as there were few studies that reported on primary clinical outcomes and no studies that explicitly analyzed harms. Many studies that reported on resource usage (primary economic outcomes) were actually reporting on clinical process outcomes, such as use of testing or prevention of hospital admissions. We included studies of perceptions of HIE only if an actual operational HIE was analyzed. For Key Question 4 there are two categories of studies: large, mostly national surveys that examined use on a macro level, which health organizations are or are not using HIE; and studies that looked at how HIE is used (or not used) within organizations. We present the evidence for Key Questions 5 (usability) and 6 (barriers and facilitators to use) jointly as some studies addressed both sets of questions together.

Similarly, we have combined the results for Key Questions 7 and 8 because conceptually, organizations consider sustainability when deciding whether or not to adopt an innovation or implement a new practice and conversely sustainability is at least partially dependent on the form and success of implementation. As a result, there is significant overlap in the research. Many of the studies we identified either address implementation and sustainability, or address implementation as well as the topics covered by other Key Questions--impact, use, or usage/usability. The focus of the results section for Key Questions 7 and 8 is on trends in facilitators and barriers. We grouped the factors identified in the literature into categories in order to facilitate a summary and to examine whether there are any trends either over time or across any identifiable subgroups.

We found clear heterogeneity in the interventions and outcomes measured, including how similar outcomes were measured and reported, such that we did not conduct meta-analyses.

Grading the Body of Evidence for Each Key Question

The strength of evidence for key outcomes was rated only for effectiveness and harms outcomes in Key Question 1 through 3 using the four categories recommended in the AHRQ Methods Guide.²⁹

- A “high” grade indicates high confidence that the estimate of effect lies close to the true effect for this outcome. The body of evidence has few or no deficiencies and the findings are stable (i.e., another study would not change the conclusions).
- A “moderate” grade indicates moderate confidence that the estimate of effect lies close to the true effect for this outcome. The body of evidence has some deficiencies and findings are likely to be stable, but some doubt remains.
- A “low” grade indicates low confidence that the estimate of effect lies close to the true effect for this outcome. The body of evidence has major or numerous deficiencies (or both) and additional evidence is needed before concluding either that the findings are stable or that the estimate of effect is close to the true effect.
- An “insufficient” grade indicates inability to estimate an effect or no confidence in the estimate of effect for this outcome, no evidence is available or the body of evidence has unacceptable deficiencies, precluding reaching a conclusion.

For a more detailed description of the methods and domains used to rate strength of evidence, see **Appendix F**.

Other outcomes (e.g., perceptions in Key Question 3) and outcomes for Key Questions 4 through 8 were not formally evaluated for strength of evidence, but key concepts of strength of evidence were discussed.

Assessing Applicability

Applicability is defined as the extent to which the effects observed in published studies are likely to reflect the expected results when a specific intervention is applied to the population of interest under “real-world” conditions.²⁹ It is an indicator of the extent to which research included in a review might be useful for informing clinical decisions in specific situations. Applicability depends on the particular question and the needs of the user of the review. There is no generally accepted universal rating system for applicability. In addition, applicability depends in part on context. Therefore, a rating of applicability (such as “high” or “low”) was not assigned because applicability may differ based on the user of this review. Rather, factors important for understanding the applicability of studies were recorded, such as differences in the organizations (e.g., payment/reimbursement model, range of services provided, governance structure, IT systems) and people (e.g., profession, type of relationship with the organization, tenure) affected by the creation and implementation of the HIE that was the subject of study, the scope of the HIE, the clinical settings involved, and the geographic area (e.g., states, regions or countries) in which the studies are performed.

Peer Review and Public Commentary

Experts in HIE, individuals representing important stakeholder groups, and TEP members have been invited to provide external peer review of this systematic review. The AHRQ Task

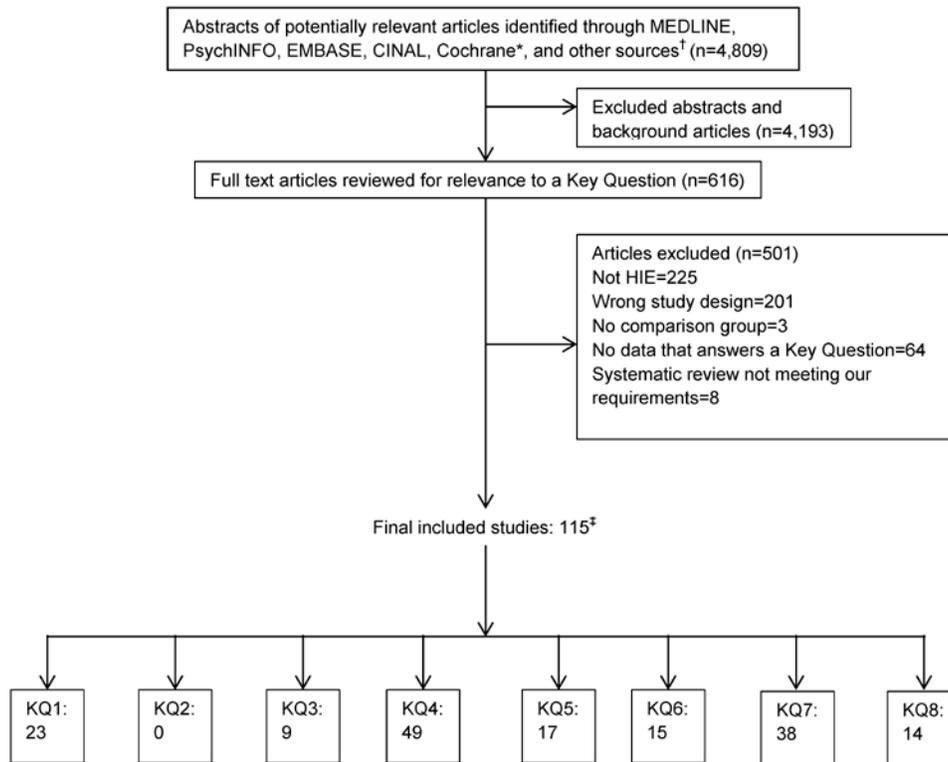
Order Officer and a designated Evidence-based Practice Center Associate Editor will also provide comments and editorial review. To obtain public comment, the draft report will be posted on the AHRQ web site for 4 weeks. A disposition of comments report detailing the authors' responses to the peer and public review comments will be made available after AHRQ posts the final systematic review on the public web site.

Results

Results of Literature Searches

Results of the literature search and selection process are summarized in the literature flow diagram (Figure 2). Database searches resulted in 4,809 potentially relevant citations. After dual review of abstracts and titles, 616 articles were selected for full-text review. After dual review of full text articles, 115 studies were included. Data extraction and risk of bias assessment tables for included studies are available in **Appendixes G and H**.

Figure 2. Literature flow diagram



Abbreviations: HIE= health information exchange; KQ= key question

*Cochrane databases include the Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, National Health Sciences Economic Evaluation Database

†Identified from reference lists, hand searching, suggested by experts, etc.

‡Studies may address more than one Key Question

Description of Included Studies

Of the 115 studies included in this review, two randomized controlled trials (RCTs) and 30 observational and survey studies addressed Key Questions 1, 2, and 3, pertaining to the effectiveness of improving clinical, economic, population, and intermediate outcomes. The majority were assessed to be of moderate risk of bias; most were conducted in the United States but some were performed in Europe, Canada, and South Korea; and most studies reported

clinical process, economic, or population outcomes, while no studies reported harms of health information exchange (HIE). We identified 49 studies that addressed Key Question 4, pertaining to the use of HIE. The majority were conducted in the United States and were low risk of bias or could not be rated due to study design. Seventeen studies were identified that addressed Key Questions 5 and 6, pertaining to usability and facilitators and barriers to use. Most were assessed to be of moderate risk of bias and were conducted in the United States, Austria, and Australia. We identified 45 studies that addressed Key Questions 7 and 8, pertaining to facilitators and barriers to implementation and sustainability. These studies were of varying types of qualitative data and analysis and for those that could be assessed, most were assessed to be of high risk of bias, were conducted in the United States, and most studies reported on facilitators and barriers to implementation.

Key Question 1. Is HIE effective in improving clinical, economic, and population outcomes?

Key Question 2. What harms have resulted from HIE?

Key Question 3. Is HIE effective in improving intermediate outcomes such as patient and provider experience, perceptions or behavior; health care processes; or the availability, completeness, or accuracy of information?

Key Points

- HIE has been researched in far fewer places than it has been implemented, resulting in a research literature skewed toward a relatively small number of sites.
- Although the potential uses of HIE are broad, most studies report on narrow questions, such as reduction in test ordering or consultations, and not larger overall clinical and financial impacts. Furthermore, most of these studies were conducted retrospectively, making cause and effect difficult to ascertain.
- The strength of evidence for HIE in improving clinical, economic, or population outcomes is low.
- Most studies also report positive results, raising concerns about publication bias.

Detailed Synthesis

We identified 31 studies that assessed some sort of outcome from HIE use (**Table 1**). Mapping to our original Key Questions, a total of 23 studies were deemed to report clinical, economic, or population outcomes (Key Question 1), while another 9 were found to report on perceptions or data quality issues (Key Question 3). However, no studies evaluated primary clinical outcomes from HIE (Key Question 1, e.g., mortality, morbidity), and none explicitly assessed harms (Key Question 2). Additionally, some studies report outcomes for more than one of these Key Questions. For these reasons, we present the results of Key Questions 1 through 3 together below.

The most common study design for assessing outcomes was retrospective cohort, typically with HIE use associated with some specific outcome factor.³¹⁻⁴⁸ The next most common design was survey, which was usually focused on perception of outcomes.⁴⁹⁻⁵⁶ Two studies were RCTs, one of a particular directed information exchange (two published papers, one on clinical outcomes⁵⁷ and the other on perceptions⁵⁸) and the other of a clinical decision support intervention using data from an HIE.⁵⁹ Two studies used cross-sectional analyses of large databases to compare those having access to HIE with those without access.^{60,61} Another study used a prospective methodology that involved asking clinicians if HIE access avoided undesirable resource use, and then calculating the costs saved.⁶²

The identified studies were performed mostly in the United States, but we identified seven studies from five other countries (Austria,⁵⁴ Canada,^{57,58} Finland,^{38,53} Israel,³³ and South Korea⁵⁵). Of the 25 U.S.-based studies, three assessed multiple HIEs in two states (1 study) and the entire country (2 studies). The remaining 22 studies were conducted (1 study per state unless otherwise noted) in Colorado,⁴² Indiana (3 studies),^{34,41,51} Louisiana,³⁹ Massachusetts,⁵² North Carolina,⁵⁹ New York (6 studies),^{37,43,47-50} Oklahoma,⁴⁰ South Carolina,⁶² Tennessee (3 studies),^{31,32,36} Texas,⁴⁶ Virginia,³⁵ and Wisconsin (2 studies).^{44,45}

The number of studies and their locations in the United States represent a small fraction of those reporting to be operational, sustainable, or innovating according to the eHealth Initiative Annual Data Exchange Survey, which reported a total of 84 such HIEs in 2013⁶³ and 106 in 2014.⁶⁴ In other words, while a substantial number of HIEs exist in the United States, only a small number have been subject to evaluation of any sort of outcomes. This low number of studies relative to HIE efforts also makes it difficult to generalize factors about aspects of HIEs, such as location, HIE type, and setting, with results of research.

In **Table 1**, we present the results of these studies by outcome category, and also classify the study geographic location, health care setting, HIE type (query vs. directed) and general direction of results. Due mainly to study design and performance or reporting limitations, and the lack of ability to combine results, this body of evidence is of low strength.

Table 1. Studies of HIE included for assessing outcomes

Study	Location	Setting	HIE type	Study type	Risk of bias	Direction of result(s)	Outcome(s) assessed	Results
Laboratory testing or cost of testing								
Mäenpa <i>et al.</i> , 2011 ³⁸	Finland, Tampere	Outpatient	Query	Retrospective cohort	Moderate	Negative	Lab test ordering	Increased lab test ordering
Ross <i>et al.</i> , 2013 ⁴²	Colorado, Mesa County	Outpatient	Query	Retrospective cohort	Moderate	Beneficial	Rate of increase in lab testing	HIE reduced rate of increase in lab testing
Carr <i>et al.</i> , 2014 ⁶²	South Carolina, Charleston	ED	Query	Prospective cohort	High	Beneficial	Lab test ordering	Reduced lab test ordering
Frisse <i>et al.</i> , 2012 ³⁶	Tennessee, Memphis	ED	Query	Retrospective cohort	Moderate	Beneficial	Overall cost	Decreased with HIE use
Tzeel <i>et al.</i> , 2011 ⁴⁴	Wisconsin, Milwaukee	ED	Query	Retrospective cohort	Moderate	Beneficial	ED visit costs	Decreased with HIE use; driven by reduced lab test orders
Radiology testing								
Bailey <i>et al.</i> , 2013 ³¹	Tennessee, Memphis	ED	Query	Retrospective cohort	Moderate	Beneficial	Use of neuroimaging	Reduced imaging
Bailey, <i>et al.</i> , 2013 ³²	Tennessee, Memphis	ED	Query	Retrospective cohort	Moderate	Beneficial	Use of back imaging	Reduced imaging
Carr <i>et al.</i> , 2014 ⁶²	South Carolina, Charleston	ED	Query	Prospective cohort	High	Beneficial	Use of radiology testing	Reduced imaging
Lammers, Adler-Milstein and Kocher, 2014 ⁶¹	California and Florida	ED	Varied	Cross-sectional	Moderate	Beneficial	Reimaging in ED	Reduced imaging among those who implemented HIE
Mäenpa <i>et al.</i> , 2011 ³⁸	Finland, Tampere	Outpatient	Query	Retrospective cohort	Moderate	Beneficial	Use of radiology testing	Reduced imaging
Ross <i>et al.</i> , 2013 ⁴²	Colorado, Mesa County	Outpatient	Query	Retrospective cohort	Moderate	None	Use of radiology testing	No impact on imaging

Study	Location	Setting	HIE type	Study type	Risk of bias	Direction of result(s)	Outcome(s) assessed	Results
Hospital admissions								
Ben-Assuli, Shabtai and Leshno, 2013 ³³	Israel	HMO	Query	Retrospective cohort	Moderate	Beneficial	Hospital admissions	Decreased with HIE use
Frisse <i>et al.</i> , 2012 ³⁶	Tennessee, Memphis	ED	Query	Retrospective cohort	Moderate	Beneficial	Hospital admissions	Decreased with HIE use
Carr <i>et al.</i> , 2014 ⁶²	South Carolina, Charleston	ED	Query	Prospective cohort	High	Beneficial	Hospital admissions	Decreased with HIE use
Tzeel <i>et al.</i> , 2012 ⁴⁵	Wisconsin, Milwaukee	ED	Query	Retrospective cohort	Moderate	Negative Beneficial	Hospital admissions Length of Stay	Increased admissions but decreased LOS
Vest, 2009 ⁴⁶	Texas, Austin	ED	Query	Retrospective cohort	Moderate	Beneficial	Hospital admissions for ambulatory-sensitive diagnoses in indigent patients	Increased with use of HIE
Vest <i>et al.</i> , 2014 ⁴⁷	New York, Rochester	ED	Query	Retrospective cohort	Moderate	Beneficial	Hospital admissions	Reduced with HIE
Hospital/ED readmissions								
Lang <i>et al.</i> , 2006 ⁵⁷	Canada, Montreal	ED	Directed	RCT	Moderate	None	ED return visits	No difference
Vest <i>et al.</i> , 2014 ⁴⁷	New York, Rochester	ED	Query	Retrospective cohort	Moderate	Beneficial	Hospital readmissions	Decreased with HIE use
Jones, Friedberg and Schneider, 2011 ⁶⁰	U.S.	All	Varied	Cross-sectional	Moderate	None	Hospital readmissions	No difference
Referrals and/or consultations								
Carr <i>et al.</i> , 2014 ⁶²	South Carolina, Charleston	ED	Query	Prospective cohort	High	Beneficial	Consultation	Reduced with HIE use
Mäenpa <i>et al.</i> , 2011 ³⁸	Finland, Tampere	Outpatient	Query	Retrospective cohort	Moderate	Mixed	Referral ordering	Increased referrals with HIE

Emergency Department Costs								
Frisse <i>et al.</i> , 2012 ³⁶	Tennessee, Memphis	ED	Query	Retrospective cohort	Moderate	Beneficial	Overall cost	Decreased with HIE use
Tzeel <i>et al.</i> , 2011 ⁴⁴	Wisconsin, Milwaukee	ED	Query	Retrospective cohort	Moderate	Beneficial	ED visit costs	Decreased with HIE use; driven by reduced lab test orders
Public health reporting								
Magnus <i>et al.</i> , 2012 ³⁹	Louisiana	Public health	Directed	Retrospective cohort	Low	Beneficial	Followup care for HIV patients	Improved with HIE
Dixon, McGowan and Grannis, 2011 ³⁴	Indiana	Public health	Directed	Retrospective cohort	Moderate	None	Completeness of public health reporting	Incomplete due to poor quality of clinical data
Overhage <i>et al.</i> , 2008 ⁴¹	Indiana	Public health	Directed	Retrospective cohort	Moderate	Beneficial	Identification and completeness of notifiable disease reporting	Increased notifiable diseases found and completeness of data for diseases found
Quality of ambulatory care								
Kern <i>et al.</i> , 2012 ³⁷	New York, Hudson Valley	Outpatient	Query	Retrospective cohort	Moderate	Beneficial	Clinical quality measures	Increased with HIE
Nagykaldi <i>et al.</i> , 2014 ⁴⁰	New York, Hudson Valley	Outpatient	Query	Retrospective cohort	Moderate	Beneficial	Clinical quality measures	Increased with HIE
Willis <i>et al.</i> , 2013 ⁵⁹	Oklahoma, Norman and Oklahoma City	Outpatient	Query	RCT	Moderate	Beneficial	Documentation and medication reconciliation	Increased with HIE
Other aspects of HIE								
Feldman and Horan, 2011 ³⁵	VA	Government	Directed	Retrospective cohort	Moderate	Beneficial	Case processing time for SSD determination	Decrease in mean case processing time
Shapiro <i>et al.</i> , 2013 ⁴³	New York	ED	Query	Retrospective cohort	Low	Beneficial	Identification of frequent ED users	Increased with HIE

Abbreviations: CDS= clinical decision support; CQI=continuous quality improvement; ED= emergency department; HIE= health information exchange; HMO= health maintenance organization; LOS= length of stay; PCP= primary care provider; PH= public health; RCT= randomized, controlled trial; SSD=Social Security Disability; VA = Veterans Affairs; vs. = versus

With the exception of two RCTs (in three publications) and one other study with a prospective design, most studies used retrospective designs, usually with the approach of comparing HIE being used in association with one or more clinical variables. All of these studies focused on the direct effect of HIE, usually in reducing resource use or costs, without determining its larger impact (e.g., overall total or proportion of spending in an emergency department [ED] vs. the total dollar amounts that HIE appeared to save). None of the studies analyzed individual episodes of care to determine clinical appropriateness of possible changes brought about by HIE use.

The prospective studies also had limitations. The RCTs were focused on highly specific uses of HIE, namely directed exchange of ED reports in one and pharmacotherapy clinical decision support in another. Of note, however, was that both of these studies showed no benefit for HIE. The other prospective study was limited by its methodology consisting of physician self-reporting of resources not utilized when HIE was used, with no followup or validation of their decisions, or analysis of more holistic views of clinical outcomes or costs.

While most of these studies had reasonable internal validity, there are major questions of external validity, especially since the intervention (HIE) is only partially associated with the clinical outcome (i.e., many more factors go into clinical outcomes than the decision to consult an HIE on a patient). As a result, most studies with appropriate retrospective methods are listed as having moderate risk of bias due to their proper internal validity but significant concerns about external validity.

Improving Resource Use

Laboratory testing. Five studies addressed laboratory test ordering, with four finding a benefit of HIE in reducing overall tests, but estimates of impact on cost was mixed.^{36,38,42,44,62} Three of these studies took place in the ED setting, all showing some aspect of reduced test ordering and cost savings. Two studies found overall reduced laboratory test ordering, with one reporting an odds ratio (OR) of testing among patients for whom HIE was accessed to be 0.880 (95% confidence interval [CI], 0.828 to 0.935)³⁶ and the other noting 23 percent fewer lab testing procedures (statistical significance not reported) in a propensity-matched group of patients for whom HIE could have been used.⁴⁴ A third study logged physician indication of laboratory test ordering averted with use of HIE in the ED, with savings over 3 months of \$462 calculated from what was reportedly not ordered.⁶² The other two studies took place in ambulatory settings, with both occurring against a backdrop of increased overall laboratory test ordering. A U.S.-based study found that after HIE implementation, there was a reduction in the increasing of the rate of test ordering but no overall cost savings,⁴² while a Finland-based study found increased laboratory testing during the period when HIE was implemented (19.0% for primary care physicians and 7.0% for specialist physicians per total patient appointments).³⁸ As with all retrospective studies, the four studies of laboratory test ordering could be complicated by confounders, while the prospective study did not validate physician designation of tests averted and did not assess the larger cost of overall care of the patient in the ED and beyond.

Radiology testing. Eight studies assessed radiology test ordering, with all but one reporting benefit in reducing testing for HIE.^{31,32,36,38,42,44,61,62} Five of these studies also studied laboratory

test ordering and were described in the previous paragraph,^{36,38,42,44,62} with three additional ED studies showing reduced ordering.^{31,32,61}

The ED studies showed a variety of findings. Frisse *et al.* found that for all radiologic imaging, there was reduced ordering of head computed tomography (CT) imaging, (OR of 0.913, 95% CI, 0.842 to 0.991) and reduced body CT imaging (OR 0.886, 95% CI, 0.828 to 0.948) but no significant difference for echocardiogram, chest x-ray, or ankle x-ray in 12 EDs.³⁶ Tzeel *et al.* demonstrated 22 percent decreased diagnostic radiology ordering and 52 percent reduced CT scan ordering (statistical significance not reported) when HIE was used in the ED.⁴⁴ Two additional studies assessed neuroimaging for headache³¹ and repeat imaging for back pain in EDs.³² For neuroimaging, HIE usage was associated with decreased diagnostic imaging (OR 0.38; 95% CI, 0.29 to 0.50) and increased adherence to evidence-based guidelines (OR 1.33; 95% CI, 1.02 to 1.73), although there were no significant changes in overall costs. HIE usage was associated with reduced repeat imaging for back pain (OR 0.36; 95% CI, 0.18 to 0.71), but no change in cost due to higher use of CT scans with HIE access. Carr *et al.* reported \$161K in savings over 3 months in reported averted radiologic test ordering in EDs.⁶²

One cross-sectional study looked at repeat imaging in the ED in two states (California and Florida), finding reduced probability of repeat CT (-8.7%; 95% CI, -14.7% to -2.7%), ultrasound (-9.1%; 95% CI, -17.2% to -1.1%), and chest x-ray (-13.0%; 95% CI, -18.3% to -7.7%) ordering in hospitals that had HIE participation as reported in the Healthcare Information and Management Systems Society Analytics Database of hospital information technology (IT) functionality.⁶¹

The one negative study came from the ambulatory setting, which was a U.S.-based study showing no statistically significant reduction in rate of radiologic test ordering.⁴² However, a Finland-based study did show a reduction in radiologic test ordering (16.4% reduction for primary care physicians and 11.0% reduction for specialist physicians).³⁸

Hospital admissions. Seven studies assessed the role of HIE in reducing hospital admissions, with inconsistent findings.^{33,36,45,46,48,57,62} Two studies (described above) found reduced admissions and cost reductions using the methods previously described. The bulk of the \$1.07 million annual savings due to HIE described by Frisse *et al.* came from reduced hospital admissions.³⁶ Carr *et al.* also reported \$118K in savings from averted admissions over a 3-month period.⁶² Another study in an Israeli health management organization found that viewing the medical history via an electronic health record (EHR) decreased possibly redundant admissions, with even higher reductions when information came from an HIE.³³ A study in New York found that viewing information reduced odds of admission (OR 0.7; 95% CI, 0.52 to 0.95).⁴⁸

Other studies, however, found no benefit from HIE in terms of avoiding hospital admissions. An RCT of directed HIE in Canada providing family physicians electronic reports of ED visits versus paper-based reports resulted in no difference in hospital admissions or return visits to the ED.⁵⁷ Other studies found that HIE was associated with increased admissions for ambulatory-sensitive diagnoses⁴⁶ and a 28 percent increased rate of admissions, although such admissions had reduced length of stay with 771 fewer bed days per 1,000 health plan members.⁴⁵

Two studies assessed HIE in reducing hospital readmissions. One study found that assessing information in an HIE was associated with reduced odds of hospital readmission (OR 0.43; 95% CI, 0.27 to 0.70)⁴⁷ while another found that hospitals participating in HIE in 2007 across the

United States did not have lower readmission rates for acute myocardial infarction, pneumonia, or heart failure.⁶⁰

Referrals and consultations. Two studies assessed HIE for reducing referrals and/or consultations. The prospective ED study by Carr *et al.* reported reduced consultations, leading to savings of \$3,990 over 3 months.⁶² The Finland-based ambulatory study, however, found that HIE was associated with increased referrals by primary care physicians (43.6%) and specialists (12.8%).³⁸

Emergency department cost. Another two studies addressed reducing overall ED costs per patient, with both finding reductions when HIE was available. One study found that an HIE encompassing 12 EDs resulted in net annual savings (total savings minus operating costs) of \$1.07 million, with reduced hospital admissions accounting for 97.6 percent of the reduction.³⁶ Another study found that for a propensity-matched group of patients for whom HIE could have been used, the group for whom HIE was used had \$29 per ED visit less expenditures.⁴⁴ Neither study reported overall ED expenditures, making it impossible to know the proportion of overall ED spending that was impacted by HIE.

Public Health Reporting. Three studies assessed HIE in public health settings.^{34,39,41} Two looked at completeness of data for notifiable disease reporting. One study compared usual (“spontaneous”) public health reporting with automated lab reporting through the HIE, finding a 4.4-fold higher rate of reporting for the HIE-based approach, with cases identified an average of 7.9 days earlier.⁴¹ The other study showed equal or improved completeness of reporting for a variety of data fields in notifiable disease reports, although completeness was reduced for some fields (e.g., laboratory units of measure, normal range, and abnormal flag) due to inadequacies in the clinical data entering the HIE.³⁴ Another study found that a public health HIE led to increased identification of needed followup care of 419 HIV patients and 85 percent of them having actual followup care.³⁹

Quality of care. Three studies looked at the value of HIE in improving quality of care in ambulatory settings.^{37,40,59} One study assessed a benchmark group of clinical quality measures believed to be amenable to HIE usage among users and non-users of an HIE portal. Users of the portal had a higher proportion of physicians exceeding mean clinical quality measure performance at baseline (57% vs. 48%) that increased after the HIE became available (64% vs. 49%), with the increase for portal users before and after availability of the HIE statistically significant ($p < 0.001$).³⁷ An RCT of HIE data used in a clinical decision support intervention was able to detect medication adherence problems in eight categories of drugs but did not show any benefit in improving adherence.⁵⁹ Another study of six physician practices found improved documentation and delivery of preventive services for mammography screening (21.1% to 57.1%, $p < 0.01$), colonoscopy screening (31.7% to 53.8%, $p < 0.01$), pneumococcal vaccine administration (39.1% to 50.6%, $p < 0.01$), and influenza vaccine administration (22.7% to 41.7%, $p < 0.01$).⁴⁰ The study also found that medication reconciliation completion improved from 35.3 percent to 44.9 percent ($p < 0.001$).

Other aspects of HIE. Two studies assessed other aspects of HIE. One study found a 30 percent reduction in evaluation time for Social Security Disability claims.³⁵ Another found that HIE data led to a 20.3 percent increase in identification of frequent ED users compared with site-specific data.⁴³

Low strength evidence mostly favors the value of HIE in reducing resource use and costs, especially in the ED. However, these studies use mostly retrospective designs that cannot account for how HIE was used and its impact on the overall care of the patient beyond the immediate setting where it was used.

Perceptions

A variety of studies evaluated aspects of clinician or patient perceptions of HIE (**Table 2**).^{49-56,58} Three studies assessed clinician perceptions of HIE in the ED setting. One study followed up an RCT on the provision of an electronic versus mailed report after an ED visit,⁵⁷ with family physicians reporting that they perceived ED followup outcomes and patient management improved.⁵⁸ Another study also found that primary care physicians reported enhanced awareness and improved communication and followup after ED admission/discharge.⁴⁹ An additional study found that physicians felt that providing pharmacy information in the ED improved knowledge and gaps but was not felt to reduce time or be worth the cost.⁵²

Other studies assessed perceptions in the outpatient setting. Two studies found that HIE was perceived to improve ambulatory care function, resulting in faster acquisition and treatment decisions⁵³ and improved care and decreased work for filing and archiving discharge reports that were sent.⁵⁴

Some studies looked at specific aspects of HIE. One study found that physicians were more satisfied with electronic lab reports than with paper-based reports.⁵¹ Another queried physicians on push versus pull HIE, with respondents reporting satisfaction with both, although more so with push over pull.⁵⁰ Another study assessed patient satisfaction when records were transferred via HIE, finding it to be improved over patients delivering paper records themselves.⁵⁵

One study focused on hospital-based HIE, finding that communication and satisfaction were higher in hospitals that implemented rather than adopted (proposed to implement) HIE.⁵⁶

Perceptions of the value of HIE by clinicians, where it has been studied, is generally positive. How these perceptions translate into improved care is unknown. This body of evidence is low strength.

Table 2. Patient and clinician perceptions of HIE

Study	Location	Setting	HIE type	Study type	Risk of bias	Direction of result(s)	Outcome(s) assessed	Results
Afilalo, <i>et al.</i> , 2007 ⁵⁸	Canada, Montreal	ED	Directed	RCT	Moderate	Beneficial	Outcomes improved, better patient management	Improved with HIE
Altman <i>et al.</i> , 2012 ⁴⁹	New York	ED	Directed	Survey	Moderate	Beneficial	PCP notification of ED admission/discharge	Enhanced awareness and improved communication and followup
Campion <i>et al.</i> , 2012 ⁵⁰	New York, Rochester and Buffalo	Outpatient	Both	Survey	Moderate	Beneficial	Physician satisfaction of push vs. pull	Satisfied with both, more with push than pull
Chang <i>et al.</i> , 2010 ⁵¹	Indiana	Outpatient	Query	Survey	High	Beneficial	Physician satisfaction with electronic lab reports	Favorable, including over traditional reports
Kaushal <i>et al.</i> , 2010 ⁵²	Massachusetts	ED	Directed	Survey	Moderate	Mixed	Impact of providing pharmacy information	Improved knowledge and gaps but not felt to reduce time or be worth the cost
Maass <i>et al.</i> , 2008 ⁵³	Finland	Outpatient	Query	Survey	Moderate	Beneficial	Improvements in care	When HIE used, faster results acquisition and treatment decision
Machan, Ammenwerth and Schabetsberger, 2006 ⁵⁴	Austria, Tyrol	Outpatient	Directed	Survey	Moderate	Beneficial	Physician satisfaction with discharge reports sent	Improved care and decreased work for filing and archiving
Park <i>et al.</i> , 2013 ⁵⁵	South Korea	Outpatient	Directed	Survey	Moderate	Beneficial	Patient perceptions of data transferred	Increased satisfaction for patients whose records transferred via HIE
Vest and Miller, 2011 ⁵⁶	U.S.	Hospital	Varied	Survey	Moderate	Beneficial	Communication and satisfaction within hospitals	Higher in implemented than adopted hospitals

Abbreviations:ED = emergency department; HIE = health information exchange; RCT = randomized controlled trial; U.S. = United States.

Factors Associated With Outcomes

To determine whether effectiveness of HIE varied by location, health care setting, or outcome type, we rated each study outcome by whether HIE was found to have some beneficial effect or not. As shown in **Table 3**, the preponderance of studies showed that HIE use for different functions, in various settings, and of varying types was mostly positive. While the number of positive versus negative studies is not an indicator of the overall direction of the evidence, we do note that for each “negative” study, there is at least one “positive one. For “Type of HIE,” there is no clear pattern of findings to suggest that one type is clearly better than another, even indirectly. The two RCTs we found were described in three papers. Two of these reported outcomes, one for each RCT, both of which showed no benefit for the HIE intervention.^{57,59} A perceptions study of one of the RCTs found perceptions of improved patient outcomes and their management.⁵⁸ These are in comparison with the observational study designs where 96 percent found beneficial effects of HIE. This is somewhat typical in comparing RCT and observational study results, likely due to confounding. For HIE setting, only Outpatient and ED have enough studies to evaluate patterns, and it seems that the outpatient setting is less likely to have beneficial results compared with the ED setting, but again based on indirect comparisons only. The sparsity of studies across the geographic settings makes identification of patterns impossible, although across studies in U.S. states the findings were positive in most studies.

Table 3. Factors that may affect outcomes

	Studies of Outcomes	Studies of Perceptions	Studies Reported as Beneficial	Studies Reported as No Benefit	Total
Study type					
Retrospective cohort	19		18	1	19
Randomized controlled trial	2	1	1	2	3
Cross-sectional	2		1	1	2
Survey		8	8		8
Setting					
All	1			1	1
Emergency department	12	3	12	3	15
Government	1		1		1
HMO	1		1		1
Hospital		1		1	1
Outpatient	5	6	9	1	11
Public health	1	2	3		3
Location					
U.S. multistate	1	2	2	1	3
Colorado	1		1		1
Indiana		3	3		3
Louisiana	1		1		1
Massachusetts	1		1		1
North Carolina	1			1	1
New York	4	3	6		7
Oklahoma	1		1		1
South Carolina	1		1		1
Tennessee	3		3		3
Texas	1		1		1
Virginia		1	1		1
Wisconsin	2		1	1	2
Austria		1	1		1

	Studies of Outcomes	Studies of Perceptions	Studies Reported as Beneficial	Studies Reported as No Benefit	Total
Canada	1	1	1	1	2
Finland	1	1	1	1	2
Israel	1		1		1
South Korea		1	1		1
HIE type					
Directed	3	7	9	1	10
Query	16	2	17	1	18
Multiple	3	1	3	1	4

Abbreviations: HIE= health information exchange; HMO= health maintenance organization; vs. =versus.

Key Question 4. What is the current level of use and primary uses of HIE?

Key Points

- Results of nationwide surveys suggest that the proportion of hospitals using HIE continues to increase, from 11 percent in 2009 to between 30 percent and 58 percent in 2012. Characteristics associated with higher use are nonprofit status, presence of an EHR system, larger market share, and larger practices.
- A variety of HIE models are employed across settings. Hospitals and ambulatory care providers both provide and use data; while laboratory services provide data and community clinics use data. At least 50 percent of these organizations are reaching an advanced stage of use of core functionalities; many supporting health care reform initiatives and advanced analytics.
- Use varies by type of health care professional, with higher use by nurses and clerks, when compared with physicians. Patient engagement remains low.
- Use is increasing in ambulatory care practices, with a 2013 estimate of 38 percent of practices using HIE. Characteristics of higher HIE use being larger practice size, practice owned by a healthsystem (vs. physician owned), and multispecialty (vs. single specialty) practice.
- HIE use in long-term care settings is low (<1%), with the consistent pattern of nonprofits enjoying wider use than for-profit entities.
- Results of regional and statewide studies that evaluate HIE use in inpatient, outpatient, community clinic, or EDs suggest that HIE is used for few patients; the extent of HIE use is low. Results of international/multi-national studies suggest the same finding.

Detailed Synthesis

We identified 51 studies that described the levels of use and primary uses of HIE (Tables 4-7). Several methods were used by investigators to answer questions about HIE use, including surveys (20 studies),^{22,63-81} analyses of HIE audit-logs (13 studies),^{32,37,46,82-91} retrospective database analyses (9 studies),⁹²⁻¹⁰⁰ and mixed methods (5 studies).¹⁰¹⁻¹⁰⁵ Two studies used focus group methods,^{106,107} one study used time-motion methods,⁵³ and another used geo-coding.¹⁰⁸

Over one-half of the studies (29 of 51) analyzed HIEs implemented over a regional or statewide area,^{32,37,46,65,66,72-75,77,79,81-91,97,103-108} while an additional 13 evaluated HIE use

nationally.^{22,67-70,76,80,92-96,98} Of those that evaluated use regionally or over a statewide area, nine studies evaluated HIEs in the state of New York,^{37,65,66,82,83,87,91,97,108} five in Texas,^{46,86,88-90} five in Tennessee,^{32,75,84,103,104} two in Indiana,^{77,81} and two in Minnesota.^{74,79} Five studies evaluated HIE in a single state (Massachusetts,¹⁰⁶ North Carolina,⁸⁵ Wisconsin,⁷³ Northeastern Ohio,¹⁰⁵ and Louisiana¹⁰⁷).

Two studies evaluated HIE use across integrated delivery systems. One exchanged data between the Department of Veterans Affairs (VA), the Department of Defense (DoD), and nonfederal care organizations,¹⁰¹ and the other between the VA and Kaiser Permanente.⁷¹ Four studies evaluated HIE use outside of the United States^{53,78,99,100} and one in multiple countries including the United States.¹⁰²

The majority of studies evaluated HIE use across inpatient and ambulatory care settings. Six studies were limited to evaluations of HIE use in hospitals,^{65,77,92,93,96,102} three of these used data from the American Hospital Association (AHA).^{92,93,96} Three studies evaluated HIE use that involved exchange of data with nursing homes or residential care facilities; one using data from the National Nursing Home Survey and the National Survey of Residential Care Facilities,⁹⁸ the other two using data from New York State.^{66,97} Three studies focused on evaluating HIE use in the ED; all of these exchanged data regionally.^{32,84,85} Two studies focused on evaluating HIE use in office settings using data from the National Ambulatory Medical Care Survey,^{80,95} three others used within state data, one from Indiana,⁸¹ and two from Minnesota.^{74,79}

The majority of studies assessed overall use of the HIE, while two assessed the use of HIE for repeated imaging in the ED,^{32,87} and two evaluated HIE for prevention or tracking of infections.^{72,77}

Twenty-two studies included data collected in 2010 or more recently,^{22,63,64,66,72,77,79-83,87,91,93-98,105,107,108} the majority of studies used data collected in 2009 or earlier.

Twenty-five of the studies were rated as being at low risk of bias;^{22,32,46,65-70,72,75,77,80,85,86,88-90,92-96,98,108} six at moderate risk of bias,^{73,74,79,81,87,97} six at high risk of bias;^{53,76,78,99,102,105} and fourteen were not rated due to the type of study design (data from audit-logs or qualitative studies).^{37,63,64,71,82-84,91,100,101,103,104,106,107}

Level of Use and Primary Uses, by Type of HIE

The majority of the studies used a variety of types of HIEs, and did not describe these in detail. Data describing the type of HIE, according to the classification system promulgated by the Office of the National Coordinator (direct, query-based, or consumer-mediated) were limited to studies wherein a specific HIE was evaluated. Of these, query-based HIEs were noted for evaluations of the MidSouth e-Health Alliance (MSeHA),^{32,75,84,103} the Central Texas HIE (I-Care),^{46,86,88-90} the Health Care Efficiency and Affordability Law for New Yorkers Capital Grant Program (HEAL-NY),⁸² and the Northeast Ohio Public Health Care System.¹⁰⁵

Level of Use and Primary Uses, by Health Care Settings and Systems

This summary of HIE use by health care setting and systems (Key Question 4b) has been combined with the summary by IT system characteristics (Key Question 4c), and data sources (Key Question 4d) to provide the summary below. Little meaningful information was found on the use of HIE by provider type (also Key Question 4b) so, when available, this information is also incorporated into this section.

Participation in HIE, Types of Data Exchanged, Characteristics of Successfully Participating Organizations (U.S.-wide Surveys)

Six studies used survey methods to investigate the frequency of data exchange and types of data exchanged across regional health information organizations (RHIOs) across the United States (**Table 4**).^{22,67-70,76} Across these studies, between 138 and 207 organizations met the definition of a RHIO; while between 20 and 81 RHIOs provided data. These data, collected from 2006 through 2012, suggest that entities most commonly providing data are hospitals (83%), followed by ambulatory settings (60%); and that the entities most commonly receiving data were ambulatory settings (95%), followed by hospitals (83%), public health departments (50%), and payers (44%).⁷⁰ Using survey data collected in 2007, Hessler, *et al.* focused on the exchange between RHIO and state and local public health departments, and found that of 138 public health agencies, 50 (36%) had no RHIO in their jurisdiction; 16 (12%) had no relationship with a RHIO, and 26 (40%) were exchanging information. Twelve of 20 RHIOs were exchanging information; seven of these (35%) with public health entities.⁷⁶ The types of data most frequently exchanged were laboratory test results (84% to 90%),^{67,70,76} inpatient data (70%), medication histories (70%) and outpatient data (60%).^{67,70} In 2008 and 2009, of 75 operational RHIOs, covering 14 percent of U.S. hospitals and 3 percent of ambulatory practices, only 13 supported the criteria for meaningful use criteria of the Health Information Technology for Economic and Clinical Health Act (3% of hospitals and <1% of ambulatory practices),⁶⁸ while by 2012, there had been a 61 percent increase in the number of operational RHIOs, from 75 to 119.²²

Two additional surveys were conducted by the eHealth Initiative^{63,64} One-hundred, ninety-nine of 315 identified HIEs completed the 2013 annual survey. These HIEs were a mix of community-based, state-based, and health care delivery organizations. Results indicate there is no single dominant model of HIE. Ninety organizations use a ‘Direct’ standards-based protocol for securely exchanging data, mostly for transitions in care. Patient opt-out was the most common consent model, although patient engagement remains low amongst organizations exchanging data. Eighty-four organizations had reached an advanced stage of operation or innovation; most took 2 years to become operational. Among organizations that responded in both 2011 and 2013, 27 more had reached stages 5 (operating), 6 (sustaining), or 7 (innovating) on the eHealth Initiative’s maturity scale, in 2013. Hospitals and ambulatory care providers are the stakeholders most commonly providing/viewing data; independent laboratories also commonly provide data. Community and public health clinics commonly view data. HIEs are focusing on functionalities to support health care reform initiatives and advanced analytics.

The number of HIEs identified and that responded in 2014 was lower than in 2013 – with 126 of 267 identified responding in 2014.⁶⁴ Again, there was a mix of community-based, state-based, and health care delivery organization-based HIEs responding. Data were provided by hospitals, ambulatory care providers, laboratories, and community/public health clinics. Data were accessed by ambulatory care providers, hospitals, community/public health clinics, and behavioral or mental health providers. Findings suggest an 11 percent increase over 2013 in the proportion of organizations that have reached stage 6 (operating) or higher (106 organizations). Uses of HIE included support for an accountable care organization to improve patient outcomes, for a patient centered medical home, for a State Innovation Model, and for a bundled payment initiative. Results suggest data exchange is reaching a point of stability and acceptance, and that organizations are settling on a set of core services offerings.

Seven studies investigated HIE use retrospectively, using U.S.-wide survey data collected for other purposes, with an information technology add-on.^{80,92-96,98} Three of these used data from the AHA,^{92,93,96} two from the National Ambulatory Medical Care Survey, (NAMCS),^{80,95} and one each from the Commonwealth Fund Health Policy Surveys,⁹⁴ the National Nursing Home Survey/National Survey of Residential Care Facilities.⁹⁶

These studies investigated overall participation in HIE use. Results suggest that HIE use by hospitals has risen from 11 percent (2009)⁶⁷ to between 30 percent and 58 percent more recently.^{93,94,96} Characteristics associated with higher use are nonprofit status, presence of an EHR system, larger market share, and larger practices.^{92-94,96} Results from the NAMCS (2011) suggest that the majority of office-based physicians reported being able to both send and receive data; 64 percent of these exchanges were through an EHR vendor and 28 percent through a hospital system. Activities included viewing laboratory results and incorporating these into the EHR, and exchanging clinical summaries with patients. Primary care providers were more likely to use HIE than specialists.⁸⁰ Results from the NAMCS (2013) suggest that 39 percent of office-based physicians reported having an HIE with other providers or hospitals. Characteristics of higher HIE use were larger practice size, practice owned by a health-system (vs. physician owned), and multispecialty (vs. single specialty) practice.⁹⁵ Finally, data from the National Nursing Home Survey (2004) and the National Survey of Residential Care Facilities Survey, both from the Centers for Disease Control, indicate that HIE use in these settings is low, with the consistent pattern of nonprofits enjoying wider use than for-profit entities.⁹⁸

Table 4. Level of use and primary uses of HIE, participation in health information exchanges, types of data exchanged, characteristics of successfully participating organizations, U.S.-wide studies

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Adler-Milstein, <i>et al.</i> , 2008 ⁷⁰	U.S.-wide	RHIOs	Varies	Survey	Low	Participation in RHIO Types of data exchanged.	-Most common entities <u>providing and receiving</u> data: 83% of hospitals; 67%-95% of ambulatory settings; 50% of public health departments; 44% of payers. -Types of data exchanged: Test results: 60%-90%; Inpatient data: 70%; Medication histories: 70%; Outpatient data: 60%; Images: 56%.
Adler-Milstein, Bates and Jha, 2009 ⁶⁷	U.S.-wide	RHIOs	Varies	Survey	Low	Types of data exchanged.	-Types of data exchanged: Test results: 84%; Inpatient data: 70%; Medication histories: 66%; Outpatient data: 64%.
Adler-Milstein, Landefeld and Jha, 2010 ⁶⁹	U.S.-wide	RHIOs	Varies	Survey	Low	Characteristics of successful participation.	-Likelihood of being operational associated with exchanging narrow set of data and involving broad group of stakeholders
Adler-Milstein, Bates and Jha 2011 ⁶⁸	U.S.-wide	RHIOs	Varies	Survey	Low	Number of operational RHIOs supporting stage 1 meaningful use; number financially viable.	-75 operational RHIOs, covering 14% of U.S. hospitals and 3% of ambulatory practices. -13 RHIOs support stage 1 meaningful use (covering 3% of hospitals and 0.9% of ambulatory practices).
Adler-Milstein, Bates and Jha, 2013 ²²	U.S.-wide	RHIOs	Varies	Survey	Low	Participation in RHIO. Types of data exchanged. Characteristic of successful organization.	-61% increase from 2011 (75 to 119 RHIOs). -Types of data exchanged: Test results: 82%; Summary records: 79%; Discharge records: 66%; Clinical summaries: 61% -Predominant organization was nonprofit.
Hessler, <i>et al.</i> , 2009 ⁷⁶	U.S.-wide	RHIOs	Varies	Survey	High	Participation in RHIO.	- <u>RHIOs</u> : -12/20 (60%) are exchanging information -7/20 (35%) with Public Health -Type of data exchanged most frequently: Test results: 86%. - <u>Public health agencies</u> : -50 (36%) have no RHIO in jurisdiction. -16 (12%) have no relationship with RHIO. -26 (40%) are exchanging information.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
eHealth Initiative, 2013 ⁶³	U.S.-wide	All	Varies	Survey	Not rated due to study design	Participation in HIE. Stage of maturity. Key findings.	-84 organizations had reached 'advanced' stage of operation, sustainability, or innovation. -27 more had reached stages 5 (operating), 6 (sustaining), or 7 (innovating) on the eHealth Initiative's HIE maturity scale in 2013 than in 2011. -Hospitals and ambulatory care providers most commonly providing/viewing data, followed by laboratories and community public health clinics. -Most took 2 years to become operational. Key findings: 1) Exchanges are focusing on functionalities to support health reform and advance analytics. 2) Patient engagement remains low amongst organizations exchanging data.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
eHealth Initiative, 2014 ⁶⁴	U.S.-wide	All	Varies	Survey	Not rated due to study design	Participation HIE. Stage of maturity. Key findings.	Provides data: 112 hospitals, 100 ambulatory care providers, 56 laboratories, 52 community/public health clinics. Accesses data: 111 Ambulatory care providers, 104 hospitals, 75 community/public health clinics, 65 behavioral or mental health providers. Key findings: 106 had reached stage 6 (sustaining) or higher on the eHealth Initiative's HIE maturity scale (an increase of 11% over 2013). 64 support an accountable care organization; 52 support a Patient Centered Medical Home; 21 support a State Innovation Model; 12 support a bundled payment initiative. Looking to the future 1) Data exchange is reaching a point of stability and acceptance. 2) Organizations are settling on a set of core service offerings. 3) As organizations mature, they will offer new and innovative services (public health has already leveraged HIE; alert notification services may help accountable care organizations to track patients).
Adler-Milstein, DesRoches and Jha, 2011 ⁹²	U.S.-wide	Hospitals	Varies	Retrospective database analysis of AHA data	Low	Participation in HIE. Characteristics of successful organizations.	11% of hospitals engaged in HIE. Use significantly higher for private/nonprofit status, greater market bed share, teaching status, large size, presence of cardiac ICU, and presence of EHR system.
Adler-Milstein and Jha, 2014 ⁹³	U.S.-wide	Hospitals	Varies	Retrospective database analysis of AHA data	Low	Participation in HIE. Characteristics of successful organizations.	30% of hospitals engaged in HIE. Use significantly higher for private/non-profit status; greater market bed share, in less competitive market. Varies widely by state.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Furukawa, <i>et al.</i> , 2013 ⁹⁶	U.S.-wide	Hospitals	Varies	Retrospective database analysis of AHA data	Low	Participation HIE. Types of data exchanged. Characteristics of successful organizations.	<ul style="list-style-type: none"> -In 2012, 58% of hospitals exchanging data, 41% increase over 2008, (p<0.01). -In 2012, 51% of hospitals exchanging with unaffiliated ambulatory providers, 36% with other hospitals outside their organization. -In 2012, 52%, 53%, 35% and 33% exchanging images, laboratory tests, care summaries, prescription lists with outside providers, respectively (39%, 51%, 40%, 55% increase, respectively) -After adjusting for hospital and area characteristics, hospitals with basic EHR and participation in health information organizations (HIOs) had highest rates of exchange activity. -In 2012, 80% of hospital with EHR and HIO were exchanging, 71% with HIO but no EHR were exchanging; 60% with EHR but no HIO were exchanging. -All consistent across different providers types and clinical information types. -Hospital characteristics associated with lower exchange rates were rural, for-profit, locations with greater Medicare part A spending.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Patel, <i>et al.</i> , 2013 ⁸⁰	U.S.-wide	Ambulatory Care	Varies	Retrospective database analysis of NAMCS data	Low	Participation in HIE. Types of data exchanged. Characteristics of successful organizations.	-31% of offices could share clinical summaries. -Of these, 76% could both send and receive. -64% of these exchanges were through an EHR vendor; 28% through a hospital-based system. -55% e- prescribe, 67% view laboratory results, 42% incorporate lab results into EHR. -State differences: the capacity to electronically exchange clinical summaries with patients varied from 55% (Minnesota) to 18% (Louisiana). -Proportion of physicians who exchange clinical summaries with other providers varied from 61% (Wisconsin) to 15% (Alabama). -Adoption of EHR strongest practice characteristic associated with exchange capacity, $p < .001$. -EHR vendors have wide range of capacities for exchange: 24% to 77%. -Primary care providers more likely to exchange vs. specialists.
Furukawa, <i>et al.</i> , 2014 ⁹⁵	U.S.-wide	Ambulatory care	Varies	Retrospective database analysis of NAMCS data	Low	Participation in HIE. Characteristics of successful organizations.	-39% of office-based physicians reported having an HIE with other providers or hospitals. -Characteristics of higher HIE use were larger practice size (vs. solo), practices owned by health-systems (vs. physician owned); multispecialty practices (vs. single specialty).
Audet, Squires and Doty, 2014 ⁹⁴	U.S.-wide	Ambulatory care	Varies	Retrospective database analysis of Commonwealth Fund Health Policy Surveys of Physician Practices.	Low	Participation in HIE. Characteristics of successful organizations.	-32% of physicians engage in HIE. -Use significantly higher for practices that have higher proportion for formal IT support, are part of an integrated system, larger practices, presence of EHR system, and receiving financial incentives. -Use significantly increased since 2009.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Hamann and Bezboruah, 2013 ⁹⁸	U.S.-wide	Nursing Homes	Varies	Retrospective database analysis of survey data from 2004 National Nursing Home Survey; 2010 National Survey of Residential Care Facilities	Low	Participation in HIE. Characteristics of successful organizations.	For profit vs. nonprofit: -Percent residential care facilities using HIE: 0.14% vs. 0.21%; p<0.00. Number of partners in HIE: 0.32% vs. 0.42%; p=0.02. -For profits less likely to participate in HIE; OR 0.663, p<0.001. -Supports hypothesis and proposed framework for why non-profits are more likely to use health IT.

Abbreviations: AHA = American Hospital Association; e = electronic; EHR = electronic health record; HIE = health information exchange; HIO = health information organization; ICU = intensive care units; IT= information technology; NAMCS = National Ambulatory Medical Care Survey; RHIO = regional health information organization
U.S. = United States of America; vs. = versus.

Transfer of Records between Integrated Delivery Systems

The VA and DoD use the Virtual Lifetime Electronic Record (VLER) system for eHealth exchange with the private sector, in the Nationwide Health Information Network (NwHIN) – a ‘network of networks’. This is a federated, pull (query-based) model for transfer of records between integrated delivery systems, using an opt-in consent approach by patients. The NwHIN allows users to pull in data from other organizations (**Table 5**). In an early study, Bouhaddou *et al.* investigated the transfer of records across three integrated delivery systems in San Diego, California – the VA, DoD, and Kaiser Permanente Southern California. They found that 264 of 363 of patients (73%) who opted in and provided valid authorization could be correlated across integrated delivery systems.⁷¹ In a recent, much larger study, Byrne *et al.* enrolled 12 sites. Of the 64,237 veterans who provided authorization and opted in, less than 0.01 percent opted in and subsequently opted out. The proportion of data matched between exchange partners ranged from 12 percent to 88 percent. The highest matching rates were accomplished using social security numbers in the matching algorithm. Data were retrieved for 2,724 unique VA patients with the exchange partner, and for 1,764 unique VA providers reviewing exchange partner data.¹⁰¹

Table 5. Level of use and primary uses of HIE, transfer of records between integrated delivery systems

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Bouhaddou, <i>et al.</i> , 2011 ⁷¹	San Diego, California	Nationwide Health Information Network (NwHIN; VA, DoD, Kaiser Permanente)	VLER	Cross-sectional study of patient records	Not rated due to study design	Transfer of records between integrated delivery systems.	Of 363 patients who opted in and provided valid authorization, 264 could be correlated across integrated delivery systems, with exchange of records between KP and VA, 2-3 per week.
Byrne, <i>et al.</i> , 2014 ¹⁰¹	U.S.	VA, DoD, private sector	VLER	Cross-sectional study of patient records	Not rated due to study design	Transfer of records between integrated delivery systems.	<ul style="list-style-type: none"> -64,237 veterans provided authorization and opted in. -31,080 (48%; range 12%-88%). -Highest matching rates with exchange partners using social security number in their algorithm. -5,524 inbound disclosures to VA from exchange partners (18/100 matched). -13,913 outbound disclosures to exchange partner. -Data retrieved for 2,724 unique VA patients with exchange partner. -1,764 unique VA providers reviewing exchange partner data. -9% of veterans for whom there was ≥ 1 disclosure to VA matched with exchange partner.

Abbreviations: DoD = Department of Defense; HIE = health information exchange; KP = Kaiser Permanente; NwHIN = Nationwide Health Information Network; SSN = social security number; U.S. = United States of America; VA = Veterans Affairs; VLER = Virtual Lifetime Electronic Record.

Participation HIE and Extent of Use by Regional or Statewide Initiatives

Nine studies described the use of HIE in the state of New York. Five of these used audit logs,^{37,82,83,87,91} two used surveys,^{65,66} one used a database of clinical data,⁹⁷ and one geocoding¹⁰⁸ (Table 6). Most of the HIEs are query-based. The studies of audit logs indicate frequent queries,^{82,83} and an increasing proportion of physicians accessing HIE over time (33% to 43% over 18 months).³⁷ Separately, of 63,305 patients enrolled from three hospitals, an average of 238 clinical event alerts were provided per day to notify ambulatory care providers of inpatient or ED admissions for their patients; a total of 42,818 events were detected over a 6-month timeframe.⁹¹ Primary HIE users varied by study. In one study, primary users were non-clinical staff in the outpatient setting and clinicians in the inpatient setting,⁸² while in another, 86 percent of sessions were with staff in an ED.⁸⁷

Abramson *et al.* conducted two statewide surveys in New York, one in 205 hospitals⁶⁵ and the other in 632 nursing homes.⁶⁶ In both, they investigated participation in HIE and the exchange of data. Their results suggest that 23 percent of respondent hospitals participate in HIE and exchange data, 37 percent participate but do not exchange data, and 40 percent do not participate. Among nursing homes 54 percent participate in HIE, with 31 percent of providers exchanging information outside the system. HIE use was highest when nursing homes had an EHR. The types of data exchanged were pharmacy (42%), labs (39%), and hospital data (39%). The seventh study was a retrospective database analysis of clinical data that described a geriatric care coordination program that used a Clinical Event Notification system to request information from nursing homes when patients were seen in the ED.⁹⁷ The authors suggested that use of the Clinical Event Notification functionality may have facilitated avoidance of 18 percent of hospital admissions, as these admissions lasted less than 48 hours. As not all studies described the type of HIE in detail, we were unable to draw any conclusions based on the type of HIE utilized. Finally, using a novel study design, Onyile *et al.* estimated the proportion of patients in the New York Clinical Information Exchange (now Healthix) system by mapping the most current zip code for each patient to the appropriate U.S. county. They found that 88 percent of patients in the system live within 30 minutes of New York's Times Square.¹⁰⁸

A series of five studies investigated HIE use in a query-based Central Texas HIE. I-Care is an HIE comprised of hospital systems, public and private clinics, and governmental agencies operating federally qualified health centers.^{46,86,88-90} Four of these studies were conducted across several facility member sites, with a fifth study across two sites.⁸⁶ For adult patients seen in the ED, use was low – in 57 percent of patients⁴⁶ and only 2.3 percent of encounters.⁹⁰ In a subset of two sites that did not have an EHR (but that mandated use of the HIE), the HIE was accessed in 21 percent of the encounters.⁸⁶ Across these studies, HIE use was higher for those with a greater number of ED visits and hospitalizations,^{46,86,90} older age, a greater number of chronic conditions,^{86,90} females, and those with fragmented care.⁸⁶ HIE use was lower for blacks and Hispanics, visits for alcohol use, injury, poisoning, an unfamiliar patient, and a busier than average day.⁹⁰ Similar results were found in the study that focused on children seen in the ED—use was greater for those less than 1 year old, who had more frequent encounters in the past and a greater number of diagnoses. Use was lower if the patient was unfamiliar, or if the day was busier than average.⁸⁹ In a companion study that investigated how use of HIE varies by job type and organization in an indigent care setting, Vest *et al.* found that the most frequent users were those whose positions were administrative, followed by social services, physicians, nurses,

public health professionals, and pharmacy professionals. The hospital was the workplace for 50 percent of users, followed by adult ED, ambulatory care, public health agency, mental health agency, and children's ED. Most clinical access took place in the ED and in public/mental health agencies. In the majority of use sessions, users accessed the system in a minimal fashion; almost all use was administrative.⁸⁸

Of the five studies conducted in the MSeHA, based in Memphis, Tennessee, three used audit-logs,^{32,84,103} one was a cross-sectional survey,⁷⁵ and one used mixed methods.¹⁰⁴ MSeHA is an HIE that facilitates data exchange across EDs and community-based ambulatory clinics. In 2007, across these studies, HIE use was low, being used for 12.5 percent of the study population.³² In another, HIE was viewed in the ED for between 3 percent and 10 percent of visits.⁸⁴ In a third, HIE was used for only 15 percent of return ED visits and 19 percent of return clinic visits; yet users reported the HIE provided additional information about histories and prevented repeat tests or procedures.¹⁰³ In the separate cross-sectional survey of 151 users, 43 percent reported using HIE less than 1 hour per week, 39 percent between 1 and 4 hours, and 18 percent, greater than 4 hours per week.⁷⁵ In a separate study of workflow, nurses accessed HIE when prompted by patients about a recent hospitalization, while providers accessed HIE for reasons beyond simply identifying a recent hospitalization. HIE access occurred at various points of care. Workflow patterns evolved over time, due to revisions in access policies and staffing changes.¹⁰⁴ Across these studies, use was higher when the HIE was accessed by nurses and clerks, versus physicians.^{84,103}

Separately, Dixon *et al.* conducted an online survey of 63 infection preventionists in six states with HIE, to gauge the awareness and engagement of these preventionists in using HIE for public health surveillance. One-half of their respondents were unaware of their organization's involvement in HIE, and only 10 percent reported their organizations used the HIE.⁷²

Nine additional studies describe HIE use at the state-level, two studies each from Indiana and Minnesota, and one each from Wisconsin, North Carolina, Massachusetts, Northeastern Ohio, and Louisiana.^{73,74,77,79,81,85,105-107} These studies used data from 2005¹⁰⁶ through 2013.⁷⁹ Methods of data collection included surveys,^{73,74,77,79,81,105} interviews,^{74,107} focus groups,^{106,107} and audit-logs.^{85,105} Each study makes a useful contribution to the HIE literature.

In an Indiana study of a coordinated antibiotic-resistance infection tracking, alerting, and prevention system, of the several thousand patients for whom email alerts were sent, approximately one-quarter were identified as having had documentation in a different hospital system of a previous infection with methicillin-resistant *staphylococcus aureus* or vancomycin-resistant *enterococcus*. Capture of this type of laboratory data was found useful.⁷⁷ Other Indiana investigators found real-time alerting helpful in prompting followup,⁸¹ as did investigators in Louisiana.¹⁰⁷ Patients were generally accepting of data sharing, as long as patient benefit was evident.¹⁰⁷ In a study of small practices (<20 physicians) in Minnesota, results revealed that no practice was fully involved in a regional HIE and that HIE was not part of most practices' short-term strategic plans.⁷⁴ In a study more recently conducted in Minnesota, intended to monitor progress toward meeting the legislative requirement that all health care providers have an interoperable EHR by January 2015, investigators found that over one-half of respondents exchanged data with affiliated or unaffiliated hospitals.⁷⁹ The Tripathi *et al.* study was unique in that researchers conducted focus groups with patients who lived in three communities that piloted the Massachusetts HIE. All three communities agreed to share all EHR data except text notes, consult letters, and scanned reports. Consumer opt-in was the preferred consent method, as

it is in VLER. Strategies identified to drive consumer opt-in included educating patients and providers about the enhanced convenience and lower costs of HIE.¹⁰⁶ Lobach *et al.* investigated the impact of the HIE on sentinel events for Medicaid patients in Durham County, North Carolina. In an analysis of almost 12,000 patients enrolled, they found that 19 percent experienced a sentinel event over a 6-month period. They concluded that the HIE was useful in population health management using HIE.⁸⁵ In a description of HIEs in Wisconsin, Foldy found that 78 percent (21 of 27) of organizations had HIE projects, some operational, others planned. Most were surveillance systems, delivering data to central registries, but a growing number served clinicians and patients.⁷³ Kaelber *et al.* investigated HIE use in the Northeast Ohio Public health care system, Care Everywhere. Of the 18 percent (74 of 412) of physicians who responded to the survey, approximately one-third of ED physicians, one-fifth of primary care physicians, and one-tenth of specialty care physicians used HIE. Use was highest when patients were older, with more comorbidities, Medicare/Medicaid insured, or black.¹⁰⁵ These results reflect the variation in the implementation and impact of HIE, providing data that are not necessarily generalizable to other settings. These data suggest that small practices are not adopting HIE, while larger health systems are. They further suggest that HIEs may be useful in exchanging data in the ED, and for surveillance of infectious diseases, that patients and providers view HIE favorably, and that patients can and do "buy-in" to the concept of HIE when the benefits are evident.

Table 6. Level of use and primary uses of HIE, participation in HIEs, extent of use, by regional or statewide initiatives

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Abramson, <i>et al.</i> , 2012 ⁶⁵	New York State	Hospitals	Varies	Survey	Low	Participation in HIE. Exchange of data	-23% of respondent hospitals participate and exchange data. -37% participate but do not exchange data. -40% do not participate
Abramson, <i>et al.</i> , 2014 ⁶⁶	New York State	Nursing homes	Varies	Survey	Low	Participation in HIE. Exchange of data	-54% participate in HIE. -OR=2.26 more likely to exchange when have EHR. -When EHR used, 60% exchange with providers within system; 31% exchange with providers outside system. -HIE highest for pharmacies (42%), labs (39%), and hospitals (39%).
Kern, <i>et al.</i> , 2012 ³⁷	Hudson Valley, New York	Hospitals and Laboratories	MedAllies Portal	Cross-sectional study of audit logs	Not rated	Extent of use.	Percent of MDs using portal: 33% months 1-6 vs. 42% months 7-12 vs. 43% months 13-18. -Mean days logged-in per month by MD: 8 (SD: 6).
Campion, <i>et al.</i> , 2013 ⁸³	Binghamton, New York	RHIO (2 hospitals and 13 ambulatory clinics)	Southern Tier HealthLink RHIO	Cross-sectional audit logs	Not rated	Extent of use.	-202,365 auto queries; 54% to hospitals, 46% to clinics. -145,668 unique patient encounters. -81, 687 consented patients. -41% of patients had at least one supported encounter.
Campion, <i>et al.</i> , 2013 ⁸²	New York State	3 RHIOs (hospital and outpatient)	Query	Cross-sectional audit log	Not rated	Extent of use.	-System access occurred in 60% to 82% of practice sites registered to use system, depending on community. -In communities A and B, users were non-clinical staff in outpatient settings; in community C, users were inpatient clinicians. -Proportions of patients whose data were accessed varied between 5%-60%. -Most frequently accessed data were patient summaries, followed by laboratory tests and imaging data.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Vest, <i>et al.</i> , 2013 ⁸⁷	Rochester, New York	RHIO (hospital and outpatient) and claims from health plans	Query	Case-control study of audit-log files	Moderate	Extent of use. Patient and provider characteristics associated with use of a HIE system to access radiology report.	-Each source organization sent average of 971 (range: 6 to 8,002) documents to 49 (3 to 106) other organizations. -User organizations accessed average of 49 (1 to 8,444) documents from 6 (1 to 17) source organizations. -Overall number of radiology reports retrieved in outpatient setting was 17 times greater than number of reports retrieved in the ED and inpatient settings combined (23,201 outpatient vs. 1,333 ED and 313 inpatient). -86,152 user sessions with associated claims files represented the activity of 1,119 different users representing 145 different workplace locations; 86% of sessions were with staff; 4% were with physicians.
Moore, <i>et al.</i> , 2012 ⁹¹	New York	RHIO; New York Clinical Information Exchange (NYCLIX; outpatient).	Not stated	Cross-sectional audit log	Not rated	Extent of use to alert ambulatory providers to patient events (patients admitted to or discharged from the hospital or ED).	Over 6 months: -42,818 events detected, on average 238 events per day. -≥1 event: 6,913 patients. -1 event: 1,879 patients. -≥10 events: 623 patients -Mean number of events in inpatients who had an event: 7.7 events. -Mean number of events in all patients: 0.7 events.
Gutteridge, <i>et al.</i> , 2014 ⁹⁷	New York	RHIO (ED)	Healthix	Retrospective database analysis of clinical data	Moderate	Extent of use for clinical event Notification.	-5,722 patients enrolled. -497 unique notifications sent for 206 patients. -219 of 497 (44%) for ED visits. -121 of 497 (55%) during normal business hours. -Hospital admissions resulted from 45% of ED visits; 18% of these lasted <48 hours, suggesting they were avoidable

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Onyile, <i>et al.</i> , 2013 ¹⁰⁸	New York	New York Clinical Information Exchange (NYCLIX)	Query	Cross-sectional analysis of zip code data	Low	Mapped most current zip code for each unique patient to the appropriate U.S. county; calculated distance from each zip code to Times Square.	-12 visits/ 100 patients within 30 miles; -0.4 visits/ 100 patients at 100 miles; -88% of patients live within 30 miles of Times Square.
Vest, 2009 ⁴⁶	Texas	Central Texas HIE (I-Care).	Query	Retrospective cohort study of audit logs	Low	Association between HIE use and resource use. Factors that predict HIE use.	-All levels of HIE information access were associated increased expected ED visits and ambulatory care sensitive hospitalizations, vs. no information accessed. -HIE used more for those that used the system more, or were sicker. -HIE not accessed for 43% of individuals -Ultimately, these results imply that HIE information access did not transform care in the ways many would expect. After adjusting for confounding factors the following factors increased the odds of HIE information access: OR 1.03 for increasing age. OR 1.13 for increasing number of chronic conditions. OR 1.63 for at least one prior year clinic visit. OR 1.96 for an ED visit in prior year. OR 2.02 for being hospitalized in 2004.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Vest, <i>et al.</i> , 2011 ⁸⁹	Texas	Central Texas: I-Care (EDs at 11 facilities participating in HIE)	Query	Case-control study of audit log files	Low	Extent of use for indigent children: association between basic/novel HIE use and resource use/patient characteristics. Novel usage=more screens.	System was accessed for 15,586 of 179,445 encounters (~9%); Basic HIE access: OR ~1.5 for over 1 vs. under 1 year old. OR ~1.5 for primary care visits in last 12 months. OR ~1.5-2 for ED visits in last 12 months. OR ~1.3 for hospitalized. OR ~1.05 for #diagnoses. OR ~0.46 if unfamiliar with patient. OR ~0.65 if busier than average. Novel HIE access: OR ~1.3 for over 1 vs. under 1 year old. OR ~2 for primary care visits in last 12 months. OR not significant for ED visits in last 12 months. OR ~1.15 for hospitalized. OR ~1.05 for #diagnoses. OR ~0.19 if unfamiliar with patient. OR NS if busier than average.
Vest, <i>et al.</i> , 2011 ⁹⁰	Texas	Central Texas: I-Care (EDs at 10 facilities participating in HIE)	Query	Case-control study of audit log files	Low	Extent of use for indigent adults: association between basic HIE use and resource use/patient characteristics.	-No access of system for 97.7% of encounters. -Users accessed the I-Care system for 2.3% of the 271,305 encounters. -Basic HIE usage (42,527) 41% of instances. -Sample was predominately Hispanic, younger, and a higher proportion of charity care recipients. After adjustment: OR ~0.76 to 0.89 (lower HIE access) for African American and Hispanics. HIE access higher for unknown or charity care. OR 4.7 vs. 2.6 for unknown payer. OR ~1.25 to 1.5 (higher access) for more ED visits, hospitalizations. HIE access lower for alcohol use, injury, poisoning, unfamiliar patient, busier than average day.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Vest and Jaspersen, 2012 ⁸⁸	Texas	Central Texas: I-Care (hospital and outpatient)	Query	Case-control study of audit-log files	Low	Extent of use; HIE use by job type, workplace. Usage patterns.	-297 users, 113 unique job titles, collapsed into administration (59% of users), social services (~15% of users), physician (~12% of users), nurse (~6% of users), public health (~6% of users), and pharmacy (~1% of users). -Workplaces: ambulatory care (~9% of users), ED (~18% of users), children's ED (3% of users), hospital (53% of users), public health agency (8% of users), or mental health agency (8% of users). -In more than 6 out of 10 sessions, users accessed the system in a minimal fashion. -Average pattern length was 2.89 screens (range 1-83 screens); 66% of all user sessions had a pattern length of only two screens. -Use was 94% administrative, roughly evenly distributed across workplaces but for dominance of hospital accesses (~38%). -Most clinical access took place in ED and public/mental health.
Vest, <i>et al.</i> , 2012 ⁸⁶	Texas	Central Texas: I-Care (outpatient-2 urban safety net clinics)	Query	Case-control study of audit-log files	Low	Extent of use. Association between HIE use and patient characteristics	-HIE accessed for 21% of encounters. -7,101 encounter-based, 1,227 retrospective. In adjusted model, access associated with: OR 1.12 for female. OR 1.16 for > 40 years. OR 1.19 of has chronic diseases. OR 1.13 if had ED visit in last 3 months. OR 1.33 if hospitalized in last 4 months. OR 1.52 if received fragmented care.
Johnson, <i>et al.</i> , 2008 ⁸⁴	Tennessee	MidSouth e-Health Alliance (5 EDs)	Query	Review of audit-log files and qualitative feedback	Not rated	Extent of use in ED. Percent of users who logged in.	HIE viewed in 3% of all visits and 10% of visits where patient had visit to another site in past 30 days. Percent of total users who logged on ranged from 0 in one site where the high was 12% to 75% by unit clerks in a site that had high use by other professions.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Bailey, <i>et al.</i> , 2013 ³²	Tennessee	MidSouth e-Health Alliance	Query	Retrospective cohort study of log data	Low	Extent of use. Repeat ED visits in which HIE was accessed vs. repeat visits in which HIE was not used for lumbar or thoracic imaging.	HIE use was low, at 12.5% of study population.
Gadd, <i>et al.</i> , 2011 ⁷⁵	Tennessee	MidSouth e-Health Alliance	Query	Cross-sectional survey	Low	Extent of use.	-151/162 users (93%) Average usage per week: <1 hour: =65 (43%) Between 1 and 4 hours: 58 (39%) ≥4 hours: 27 (18%)
Johnson, <i>et al.</i> , 2011 ¹⁰³	Tennessee	MidSouth e-Health Alliance (12 EDs and 9 safety net clinics)	Query	Audit logs, Comment cards, Feedback in system, Interviews, Observations, ED claims	Not rated	Extent of use. Type of data accessed. Provider log on rates. Participant opt-out rates.	-Access increased from 4% to 7% of patient encounters over 24 months, ranged from 1% to 16 % across sites. -15% for return ED visits and 19% for return clinic visits. -HIE access higher where nurses and clerks involved and lowest where MD only accessed. -Patient opt-out rates were 1-3%. -Primary user reported consequence of HIE: provided additional history (29%); prevented repeat test or procedure (20%).

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Unertl, Johnson and Lorenzi, 2012 ¹⁰⁴	Tennessee	MidSouth e-Health Alliance (6 EDs and 8 ambulatory clinics)	Query	Direct observation at 14 sites, informal interviews at sites, 9 semi structured telephone interviews 2009	Not rated	Workflow patterns, by job description.	Cross organizational patterns; 2 workflow models identified 1. Nurse workflow: prompted by patient reporting recent hospitalization event during intake, HIE access by nurse or assistant, printed discharge summary, added to chart 2. Physician workflow: HIE accessed by provider (doctor or nurse practitioner) for greater reasons beyond hospitalization; HIE access occurred at various points of care; HIE review of more information including history -Other observations: clerks tracked biopsy results; workflow patterns evolved over time, due to factors such as access policies or staffing changes; residents logged into other EMR due to lack of HIE access. -Reasons to access HIE: visit to another hospital; issues of patient trust; communication challenges; referrals.
Dixon, Jones and Grannis, 2013 ⁷²	6 states	HIE	Varies	Online survey	Low	Extent of use. Awareness and engagement of infection preventionists in HIE for public health surveillance.	-10% of infection preventionists reported their organizations were formally engaged in HIE. -49% were unaware of organizational involvement in HIE. -<5% reporting via secure email, web-based entry, through EHR, or through HIE. -72% in organizations with EHR -20% involved in implementation of EHR
Kho, <i>et al.</i> , 2013 ⁷⁷	Indiana	Indiana network for Patient Care. 5 hospital systems (17 hospitals).	Not stated	Retrospective cohort study with companion survey	Low	Extent of use. Coordinated antibiotic-resistant infection tracking, real-time alerting, and prevention	In 3 years: -12,748 email alerts sent on 6,270 unique patients. -23% (MRSA) and 22% (VRE) had previous history identified at a different hospital system. -Of 10 infection preventionists surveyed, most recommended to add automated capture of laboratory data.
Anand, <i>et al.</i> , 2012 ⁸¹	Indiana	Primary care physician offices.	Indiana HIE	Survey	Moderate	Extent of use. Effect of real-time alerting from ED, on physician action	-35% found information helpful vs. 20% not helpful. -24% made follow-up call to patient vs. 4% sent attached letter

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Fontaine, <i>et al.</i> , 2010 ⁷⁴	Minnesota	9 primary care practices with fewer than 20 physicians.	Not stated	Questionnaires & interviews	Moderate	Extent of use.	No practice was fully involved in a regional HIE. HIE was not part of most practices' short-term strategic plans.
Soderberg and Laventure, 2013 ⁷⁹	Minnesota	1,623 clinics	Varies	Survey	Moderate	Extent of use. To monitor progress toward meeting the legislative requirement that all health care providers have an interoperable EHR by January 2015.	-54% exchange data with affiliated hospitals. -36% with unaffiliated hospitals. -Common challenges for HIE: limited capacity of others to exchange, lack of technical support or expertise, competing priorities, cost and privacy concerns.
Foldy, 2007 ⁷³	Wisconsin	HIEs	Not specified; varies	Cross-sectional survey	Moderate	Extent of use. Description of projects, stages, users, organizational home, governance, scope.	-21 of 27 organizations had HIE. -21 organizations sponsored 16 (76%) operational and 11 (52%) planned HIEs projects. Most were surveillance systems, but a growing proportion served clinicians and patients. -Most advanced HIE project had 40% of respondents in implementation and 40% in operation phases. -44% delivered data only to central registries, 50% delivered to providers and registries. -63% based in government organizations.
Lobach, <i>et al.</i> , 2007 ⁸⁵	North Carolina	RHIO	Northern Piedmont Community Care Network (outpatient)	Retrospective cohort study	Low	Extent of use. Frequency and types of sentinel events.	-Of 11,899 continuously enrolled patients from a single county over a six-month period, 2,285 unique patients (19%) experienced 7,226 sentinel health events. Frequency of types of events: -43 hospital admissions for asthma. -76 hospital admissions for diabetes. -2,546 low-severity ED visits. -1,728 ≥ 2 missed appointments in 60 days.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Tripathi, <i>et al.</i> , 2009 ¹⁰⁶	Massachusetts	Massachusetts eHealth Collaborative	Not stated	Consumer (patient) focus groups	Not rated	Type of patient consent; Types of data to share.	Discussion of experience/lessons learned: 1. Decision on consent: opt in chosen due to state law stricter than federal HIPAA law; use of centralized data repository; and consumer feedback. 2. All 3 communities agreed on what to share - all EHR data except text notes, consult letters and scanned reports. 3. Consumer focus groups identified themes to drive HIE/opt-in: promote convenience and costs, promote with providers, state benefits up front, confront risks, use professional marketing. 4. Consumer Opt-in across 2 smaller communities were 88% and 92%.
Herwehe, <i>et al.</i> , 2012 ¹⁰⁷	Louisiana	Louisiana Public Health Information Exchange	Not stated	Focus groups, interviews, message logs	Not rated	Extent of use. Counts of real-time alerts and responses. Perceptions of patients.	In the 2 year period 2/1/2009 to 1/31/2011: -488 registrations of 345 unique patients with HIV identified. -Clinicians responded to 73% of alerts and documented actions on note that was shared with public health. -Results include statement that 'no negative feedback has been received from providers' with no detail. -Summary of patient interviews found general acceptance of data sharing as long as there was patient benefit and a preference for care in the health care verses the public health system. -Challenges: concerns about data ownership and ethics and disparate data systems, but these are reported as challenges they were able to address.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Kaelber, <i>et al.</i> , 2013 ¹⁰⁵	Ohio	Northeast Ohio Public Health Care System (10 hospitals and affiliated practices using Care Everywhere)	Query	Surveys and audit logs	High	Extent of use. Characteristics of patients. Perceptions of users.	Usage of HIE: -Overall: 1.3%. -ED: 3.6%. -Primary care: 2%. Specialty care: 0.5%. -Usage highest among patients who were older, with more co-morbid illness, Medicare/Medicaid insured, and black. -Self-reported impact was more efficient care (93%), time savings (85%), prevented admissions (15%), decreased tests ordered (84%), decreased imaging ordered (74%), and improved care in other ways (82%)

Abbreviations: ED = emergency department; EHR = electronic health record; EMR = electronic medical records; HIE = health information exchange; HIPAA = Health Insurance Portability and Accountability Act; MD = medical doctor; MRSA = methicillin-resistant *Staphylococcus aureus*; NS = not significant; NYCLIX = New York Clinical Information Exchange; OR = odds ratio; RHIO = regional health information organization; U.S. = United States of America; VRE = vancomycin-resistant enterococci; vs. = versus.

Extent of Use, Types of Information Exchanged, and Adoption in International or Multi-National Settings

Four studies that evaluate the use of HIEs in non-U.S. settings met our inclusion criteria, one in Australia,⁹⁹ one in South Korea,⁷⁸ and two in Finland^{53,100} (**Table 7**). A multi-country study, that included data from the United States comprises the fourth study in this group.¹⁰² Lee *et al.* found that the data most commonly transmitted differed by setting. From the hospital it was working diagnosis; from the clinic, it was clinical findings. The most useful data were laboratory or imaging data.⁷⁸ Silvester and Carr found that commitment and interest in adoption increased over time.⁹⁹ Maenpaa *et al.* also found a steady increase in uses over time by physicians, nurses and administrative staff.¹⁰⁰ Maass *et al.* conducted a unique time-motion study of HIE-facilitated care of 20 diabetic patients, and found that of 20 visits, four involved use of HIE, with one facilitating a faster treatment decision and three providing access to the most recent test results.⁵³ Finally, Jha *et al.* assessed HIE adoption by physicians and hospitals in six developed countries (United States, United Kingdom, Canada, Germany, the Netherlands, Australia, and New Zealand), and reported varying results, but they did find generally low use due to a variety of identified barriers that prevented fuller adoption. In the United States, fewer than 12 percent of organizations were exchanging data on less than 1 percent of involved populations.¹⁰² These early reports suggest that HIE in developed countries was in the initial stages of use in the early years of the 21st century.

Table 7. Level of use and primary uses of HIE, extent of use, types of information exchanged, and adoption, in international or multi-national settings

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Lee, <i>et al.</i> , 2012 ⁷⁸	Seoul, Korea	Hospital and 35 clinics	Not specified	Pre-post surveys	High	Types of information exchanged.	Most commonly transmitted information differed by setting: -From hospital was working diagnosis: 99% vs. 71% for clinic, $p < 0.0001$. -From clinic it was clinical findings: 80%, but this did not differ from hospital. -Most useful was laboratory or imaging in both settings but it was more frequently rated as useful by hospitals (88% and 7% of cases $p < 0.0001$)
Silvester 2009	Brisbane, Australia	RHIO	Not specified	Retrospective database analysis of clinical information	High	Extent of use.	-Mean events uploaded for each patient record during 12 months: 9.7 -Increased HIE use by nurses. -Number of patients registered increased from 474 (July 2007) to 1,320 (June 2008). -Increased commitment to use. -Interest to adopt by others.
Maass, <i>et al.</i> , 2008 ⁵³	Finland	RHIO	Not specified	Time-motion study of HIE-facilitated care of 20 diabetic patients	High	Extent of use.	Of 20 visits, 4 involved use of information system, with 1 allowing faster treatment decision and 3 providing access to latest test results.
Mäenpää, <i>et al.</i> , 2012 ¹⁰⁰	Finland	RHIO	Not specified	Audit log	Not rated	Extent of use.	- HIE utilization rates increased annually in all 10 federations of Municipalities. -Viewing of reference information increased steadily in each professional group over the 5-year study period. -No associations detected between use of HIE and test ordering outcomes. Frequency of laboratory test and imaging increased. The higher the numbers of emergency visits and appointments, the higher the numbers of emergency referrals to specialized care, viewed references, and HIE usage among the groups of different health care professionals.

Study	Geographic location	Setting	HIE type	Study type	Risk of bias	Outcome(s) assessed	Results
Jha, <i>et al.</i> , 2008 ¹⁰²	U.S., U.K., Canada, Germany, Netherlands, Australia, New Zealand	Physicians and hospitals	Varies	Literature review, available surveys, (Medline and Google) and Interviews with governmental and non-governmental experts	High	HIE adoption in developed countries.	Australia: Early pilots, but no major investment. Lack of unified patient ID an issue. Canada: Province-wide efforts, particularly Alberta; national—early development of 'Health Infoway' but little info exchanged. Germany: Most computers with records not connected; Germans have smart cards, but only administrative data now. Netherlands: National 'SwiPoint' pilot with 20% of population, plan full implementation in 2008. New Zealand: Planning stage, have unified patient ID, focus of discharge, laboratory and pathology reports to general practitioners. U.K.: National Programme, but mostly small amount of data exchanged in more minor programs. U.S.: RHIOs, but <12% of organizations exchanging data and <1% of population involved.

Abbreviations: HIE = health information exchange; ID = identification; RHIO = regional health information organization; U.K. = United Kingdom; U.S. = United States of America; vs. = versus.

Summary of Level of Use

In summary, HIE use was in its infancy in the early part of the 21st century, and is steadily increasing over time. Many regions and statewide initiatives are underway. HIE is used by a variety of health care professionals, for a variety of purposes, frequently to exchange information about laboratory tests, imaging tests, administrative data, and infectious disease surveillance. HIE is particularly useful in the ED and in the ambulatory setting to alert providers to inpatient or ED events recently experienced by patients. Patients also seem willing to consent to data exchange, as long as the benefits of doing so are clear to them.

Key Question 5. How does the usability of HIE impact effectiveness or harms for individuals and organizations?

Key Question 6. What facilitators and barriers impact use of HIE?

Key Points

- The 17 studies of usability did not relate usability to effectiveness or harm.
- The evidence was insufficient to compare usability by type (query-based/directed exchange, centralized/decentralized) or setting of HIE.
- Average weekly use of HIE was positively related to perceptions of usability (4 studies). The most frequent users rated usability higher than infrequent users.
- The three most commonly cited barriers to HIE use were: incomplete patient information (7 studies); inefficient workflow (8 studies); poorly designed interface and update features (5 studies).
- Sites with proxy-users (e.g., nurses, registrars) in the workflow reported the highest HIE use.
- Comparison of facilitators and barriers by type of HIE was difficult as almost all studies used a query-based approach (vs. a directed exchange).
- Incomplete patient information was a barrier to HIE use, with some settings (e.g. a clinic for the homeless) having less success in matching patients. Opt-out, where the patients are enrolled in an HIE unless they opt-out, approaches to patient enrollment may reduce this barrier, as rates of patient participation were similar for opt-in and opt-out models.
- Poorly designed interfaces proved to be a barrier to use. For example, large amounts of information required users to read several screens and resulted in slow system response.

Detailed Synthesis

We identified 17 studies that addressed either Key Question 5 or 6, or both (Table 9).^{50,54,71,75,84,101,103,104,109-117} All studies included qualitative methods and four studies were of mixed methods that included qualitative methods and some form of log or audit of actual use.^{71,84,101,103} Across all studies, 11 different HIEs were evaluated for usability, barriers, and/or facilitators to use. All but two of the studies described experience with HIEs in the United States.^{54,111}

Usability of HIE and Impact on Effectiveness or Harms

Usability has been defined in the 1998 International Standards Organization 9241-11 standard as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.”⁷⁵ To be effective and avoid harms, the HIE must be consistently used by providers and organizations so that patient information is complete and up-to-date at time of health care decisionmaking without creating burden on the clinical team.

Usability of HIE was examined in four surveys of HIE users.^{75,111,113,117} Two studies had low risk of bias,^{75,117} one had moderate risk,¹¹³ and one had high risk if bias.¹¹¹ Usability features were examined in relation to actual use in one cross-sectional study of health care professionals using the MSeHA HIE system.⁷⁵ Health professionals were emailed the survey and responded to questions about actual use and usability features that included questions from the Questionnaire for User Interface Satisfaction (QUIS) 7.0 instrument in six areas: overall reactions, screen, terminology and system information, effort required to learn the system, system capabilities, and system functionality. Multivariate analyses revealed that average weekly use of the MSeHA HIE was associated with higher scale scores in: overall reactions (OR 1.50, $p < 0.01$), learning (OR 1.32, $p < 0.05$) and system functionality (OR 1.34, $p < 0.01$). The reported psychometrics for the survey questionnaire (inter-scale agreement reliability on the QUIS scales: Cronbach’s Alpha ranging from 0.74 to 0.91) and response rate (165 of 237, 70%) were good, reducing concern about bias and increasing ability to generalize. In a mixed methods study of current and intended users of five HIE systems, the composite score for perceived ease of use (which was a composite agreement score for 10 statements on use) averaged 3.9 on a 5.0 scale where 5.0 was “strongly agree.”¹¹⁷ For example users were asked to provide level of agreement for, “Learning to operate ‘the HIE’ was easy for me.” Similarly, the same respondents averaged 4.0 of 5.0 on the perceived usefulness composite score, which was also based on responses to 10 statements. The survey sample included 24 case managers, 21 medical providers, and 17 non-clinician staff members and perceptions about usability did not vary by role. This emailed survey achieved a 62 percent (62 of 102) response rate and the inter-scale agreement reliability, Cronbach Alpha ranged from 0.57 to 0.93.

Satisfaction with HIE

Satisfaction with HIE, a measure of usability, was examined in two mixed methods studies^{111,113} and one cross-sectional study that focused on types of HIE, described later.⁵⁰ These studies had moderate-to-high risk of bias. Using a pre-post survey study design ($n=29$), physicians at one clinic and five AIDS service organizations in North Carolina reported increased satisfaction after the Carolina HIV Information Cooperative (CHIC) RHIO was implemented.¹¹³ This study was rated as moderate risk of bias. Participants reported improved satisfaction with ease of data exchanged using CAREWare software and good use of resources with CAREWare. They also reported improved relations with HIV care partners and improved patient care after implementing the RHIO. By contrast, before implementation, the providers had high expectations for how HIE would affect their work and reported some unmet expectations afterward. In a second satisfaction study of HIE users in Adelaide, South Australia,¹¹¹ users who embraced the use of the integration tools were significantly more likely to rate integration higher than those who were not using it as often ($p < 0.001$). This result echoes a more recent study that found frequent users are more pleased with the usability of the HIE than infrequent users.⁷⁵ The

response rate for the Massy-Westropp study was 24 percent (55 of 132). While both satisfaction studies^{111,113} provide descriptive evidence from surveys that users were satisfied with usability, neither provided sufficient details in the methods sections to eliminate bias or to enable generalization.

Usability of HIE by Type

We then examined whether certain types of HIE systems (direct vs. query-based; centralized vs. decentralized) were more usable. Directed exchange is provider-to-provider electronic exchange of patient information to coordinate care.²⁶ In query-based systems, the user accesses a system, queries for information (e.g., ED, hospital admissions or discharges) on a particular patient and pulls data from multiple health care organizations.⁵⁰ In centralized models, the user can query one central data repository. In federated (or decentralized) models, the user may need to query a few secured data sources, called “vaults,” managed by the participating organizations.⁷⁵ For example, the MSeHA in Memphis, Tennessee is a decentralized, query-based HIE that provides evidence in five of the 16 studies (**Table 8**). When available, the type of query-based model (centralized or decentralized) was reported but data were insufficient to compare usability based on type of HIE model.

All 17 studies described query-based exchange and four studies also provided some type of directed exchange or alert about new HIE information.^{54,110,111,115} In the multi-site case study of three RHIOs, users queried for patient information but also directly received Continuity of Care Documents (CCD).¹¹⁰ In a qualitative study, physicians received discharge summaries and images via secured email that could be integrated into existing systems.⁵⁴ In a mixed method study,¹¹¹ providers in a home-based aging community services organization received an alert that one of their patients was discharged from the hospital.¹¹¹ To retrieve the information, the provider or staff member could then log on to retrieve the hospital reports. In a qualitative study, providers could link to existing HIE information directly through their own EHR systems.¹¹⁵ These HIE data could be imported into their own EHR.

Only one cross-sectional study, of moderate risk of bias, evaluated clinician satisfaction with query-based (pull) versus direct exchange (push).⁵⁰ In this comparison study, clinicians had access to “pushed” HIE through use of certified EHRs; physicians who ordered tests could designate other physicians to receive the test results. The physicians in this study could also query (pull) for test results ordered by physicians across the greater Buffalo and Rochester areas of New York. More providers reported using push HIE (80%) than and pull HIE (53%). A greater proportion of physicians reported using push HIE always or most of the time (68%) compared with pull HIE (19%, $p=0.001$). The physicians were more satisfied with push HIE than pull HIE ($p<0.05$).

Facilitators and Barriers Impacting HIE Use

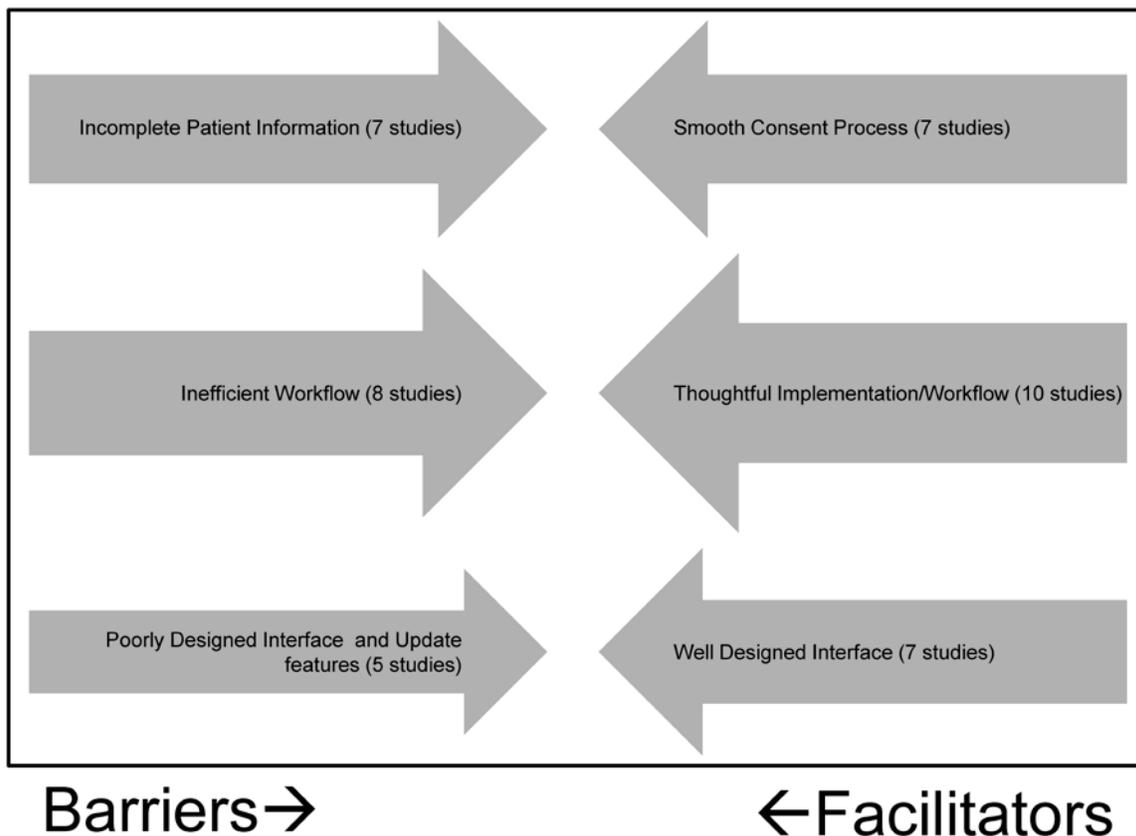
We identified many barriers and facilitators to HIE use in the literature. Evaluations of the MSeHA HIE system provide the most complete evidence on HIE barriers and facilitators of use^{75,84,103,104,116} but other studies echoed similar barriers.^{54,71,101,109,110,112,114,115,117} Barriers and facilitators were assessed with qualitative approaches in these studies which were difficult to assess for risk of bias and generalizability. In this section, the barriers mentioned most often are presented in partnership with affiliated facilitators (**Table 8** and **Figure 3**).

Table 8. Barriers and facilitators of actual HIE use grouped by theme

Barriers	Studies of barriers	Facilitators	Studies of facilitators
<p>Incomplete patient HIE Information</p> <ul style="list-style-type: none"> • Patients concerned about privacy and security • Poor matching of patients • Providers stop using query-based system when can't find patients • Patients outside of the HIE catchment area 	<p>Bouhaddau, <i>et al.</i>, 2011⁷¹ Byrne, <i>et al.</i>, 2014¹⁰¹ Hincapie, <i>et al.</i>, 2011¹⁰⁹ Kierkegaard, Kaushal and Vest, 2014¹¹⁰ McCullough, <i>et al.</i>, 2014¹¹² Rudin, <i>et al.</i>, 2011¹¹⁵ Thorn, Carter and Bailey, 2014¹¹⁶</p>	<p>Smooth consent process for patients</p> <ul style="list-style-type: none"> • Consider Opt In vs. Opt Out • Obtain consent at Registration • Educate patients on HIE • Make HIE visible to patients (turn screen so they can see it during visit). 	<p>Bouhaddou, <i>et al.</i>, 2011⁷¹ Byrne, <i>et al.</i>, 2014¹⁰¹ Campion, <i>et al.</i>, 2012⁵⁰ Kierkegaard, Kaushal and Vest, 2014¹¹⁰ Messer, <i>et al.</i>, 2012¹¹³ Johnson, <i>et al.</i>, 2011¹⁰³ Unertl, Johnson and Lorenzi, 2012¹⁰⁴</p>
<p>Inefficient workflow</p> <ul style="list-style-type: none"> • Separate login to portal – too many clicks. • Reports in HIE may not meet needs of the provider • Unmet expectations • Policy that prohibits proxy users • Need for more technical support 	<p>Byrne, <i>et al.</i>, 2014¹⁰¹ Johnson, <i>et al.</i>, 2011¹⁰³ Kierkegaard, Kaushal and Vest, 2014¹¹⁰ Machan, Ammenwerth and Schabetsberger, 2006⁵⁴ Messer, <i>et al.</i>, 2012¹¹³ Myers, <i>et al.</i>, 2012¹¹⁷ Rudin, <i>et al.</i>, 2011¹¹⁵ Thorn, Carter and Bailey, 2014¹¹⁶</p>	<p>Thoughtful implementation and workflow</p> <ul style="list-style-type: none"> • Provide training for providers and proxy users • Manage expectations of new HIE • Develop workflow for providers and proxy users. • Have providers and proxy-users involved in design of interface • Have champion HIE users • Have sufficient technical support 	<p>Byrne, <i>et al.</i>, 2014¹⁰¹ Gadd, <i>et al.</i>, 2014⁷⁵ Hincapie, <i>et al.</i>, 2011¹⁰⁹ Kierkegaard, Kaushal, and Vest, 2014¹¹⁰ Johnson, <i>et al.</i>, 2008⁸⁴ Johnson, <i>et al.</i>, 2011¹⁰³ Messer, <i>et al.</i>, 2012¹¹³ Rudin, <i>et al.</i>, 2011¹¹⁵ Thorn, Carter and Bailey, 2014¹¹⁶ Unertl, Johnson and Lorenzi, 2012¹⁰⁴</p>
<p>Poorly designed interface and update features</p> <ul style="list-style-type: none"> • Too much information & slow response • Duplicate Information • Competing use with existing patient portal with complete information • Lack of notes to set context in patient information • HIE not updated in real time 	<p>Kierkegaard, Kaushal and Vest 2014¹¹⁰ Myers, <i>et al.</i>, 2012¹¹⁷ Thorn, Carter and Bailey, 2014¹¹⁶ Machan, Ammenwerth and Schabetsberger, 2006⁵⁴ Rudin, <i>et al.</i>, 2011¹¹⁵</p>	<p>Well designed interface</p> <ul style="list-style-type: none"> • Monitor quality of data against standards • Consider when to push and when to pull • Include providers and proxy users in design of interface • Provide clear notifications of HIE • Send brief report first • Automatic integration with existing provider systems 	<p>Bryne, <i>et al.</i>, 2014¹⁰¹ Campion, <i>et al.</i>, 2012⁵⁰ Kierkegaard, Kaushal and Vest, 2014¹¹⁰ Machan, Ammenwerth and Schabetsberger, 2006⁵⁴ Massy-Westropp, <i>et al.</i>, 2005¹¹¹ Thorn, Carter and Bailey, 2014¹¹⁶ Myers, <i>et al.</i>, 2012¹¹⁷</p>

Abbreviations: HIE= Health information exchange; vs. = versus.

Figure 3. Opposing forces of barriers and facilitators to the use of HIE reported in more than one study



The barriers are opposed by oppositely themed facilitators. The number of studies related to a barrier/facilitator is shown graphically as the thickness of the arrow and also in parentheses. The supporting references are presented in the Table 8 .

Barriers of Incomplete Patient Information

Concern was expressed in several studies about incomplete patient information in the HIE.^{71,101,109,110,112,114-116} Underlying reasons for the missing data include inability to identify patients, concern about privacy, and poor patient consent process. Patients concerned with privacy and security may not understand the benefits of HIE and/or may not consent to have their data shared with other providers. Even when they do consent, they may not be properly matched to existing data.¹⁰⁹ Also, match rate can vary by population and setting; for example, the match rate for providers practicing in a homeless center was lower, but the match rate for ED physicians was higher.¹⁰⁹ Some contributing providers reported legal concerns for sharing patient data and may choose to not participate. The end result was that providers searching the HIE system may grow frustrated at taking the time to search for patient information and stop using the system.

To overcome the barrier of incomplete patient information, several approaches have been suggested to address concern about privacy and to enroll patients. To address patient and provider concern about privacy, create clear understanding about privacy and data sharing among all stakeholders (providers, patients, non-clinician partners) prior to implementation.¹¹³ In planning an HIE, several authors noted the importance of deciding whether to have opt-out or opt-in consent process for patients.^{50,71,84,101,103,104,110,114,115} Of veterans interviewed 90 percent were positive about the VLER HIE system. At the same time, 81 percent felt each person should have a choice to opt in and the default should not be automatic participation.¹⁰¹ Opting in protocols seem to yield a high patient participation rate (93% to 97%).^{50,110,115} When age is considered, more older patients opt-in than younger patients.⁷¹ The percentage of consented patients can be increased with a workflow that includes front staff members being trained to educate and consent patients as they first arrive.¹¹⁰ Additionally, patient awareness of provider use of the HIE may increase patients perception of the benefits of HIE. Patients in the VA reported being unaware that providers were using the VLER system to access information outside of the VA.¹⁰¹ The authors noted that the user interfaces of the VLER are not visible by patients because the display faces the providers. We identified one HIE that uses an opt-out protocol (MSeHA).^{103,104} Patients have the option to opt out at every encounter. The opt-out rate was 1 to 3 percent,¹⁰³ which is slightly better than programs with an opt-in protocol that lose 3 to 7 percent of patients who do not consent.^{50,115}

Barriers of Inefficient Workflow in Using an HIE

Often the HIE required a separate login and was not well integrated with the EHR.^{101,110,113,116} Additionally, some workflows made it difficult to get HIE privileges so those with privileges were called upon to look up information for those without.¹¹⁶

Sites with proxy users (registrars, nurses, clerks, other physicians) who accessed the HIE and then provided the information to the attending physician had the highest HIE access rates.^{84,103} Proxy use was described as a way to save provider time or address needs of limited users without HIE privileges.^{109,115,116}

An ethnographic qualitative study of the MSeHA HIE identified two role-based workflow models: physician-based and nurse-based.¹⁰⁴ These investigators completed 180 observation hours of six EDs and eight ambulatory clinics using the MSeHA HIE system, informational interviews during observation, and nine semi-structured interviews. In the nurse-based model, if a patient mentioned a recent hospital visit, the triage nurse or medical assistant would access the HIE primarily looking for summary documents related to recent hospital visits, such as a discharge summary, but rarely searched for other medical history. The nurse then printed off the information for use by the provider. In the physician-based model, physicians and nurse practitioners accessed the HIE for more reasons than hospital visits. These providers browsed online medical history and accessed the HIE throughout the visit for purposes of decisionmaking. Finally, another study of the MSeHA reported that HIE use dropped significantly after a new policy prohibited registrars from searching HIE at the start of a visit.¹⁰³ Initially registrars would print off a summary sheet of available HIE data. Providers then checked the HIE, based on the summary sheet. When a new policy came in place prohibiting registrars and nursing team members access for security reasons, HIE use dropped significantly.

During implementation several other strategies were mentioned related to changing current workflow: providing training and enough technical support to support the new workflow,^{75,101}

addressing needed culture change¹¹⁶ and having champion users.^{84,110} These studies also encouraged sites to manage expectations upfront¹¹³ and have a pilot implementation prior to launch so users aren't disappointed.^{103,109}

Barriers of Poorly Designed Interface and Update Features

Several design features of the HIE created barriers to use.^{54,101,110,115,117} While HIE users understood why textual notes were not included in the HIE for confidentiality reasons, this lack of context made the HIE less valuable.¹¹⁵ While some users wanted more information, other users wanted shorter reports to avoid having to scroll up and down, click on many pages or go to another task and/or complained that the HIE contained too much information that was not filtered enough to be meaningful for providers.^{110,116,117} They reported that reading a paper report was much faster than reviewing the information in the HIE.¹¹⁷ This finding was echoed by another study that recommended the main findings should be sent first in a brief report.⁵⁴ The design features could be addressed better at the implementation phase by including more providers during the design phase.¹¹⁰ Another facilitator is to continually monitor the quality and usability of the HIE data to insure that it meets standards and the needs of the users.¹⁰¹ Similarly, as more patient data and more types of data were exchanged, users reported that their HIE system response slowed suggesting the need to continually review (and reduce) what was being exchanged.¹⁰¹

Some users expressed concern with how quickly the HIE was updated and found it more efficient to go directly to the partnering clinic or hospital for information than to rely on current information in the HIE.¹¹⁷ Systems that automatically integrate with the providers' EHRs may reduce this concern and also reduce need for users to have to login into multiple systems.^{54,116}

Table 9. Summary of evidence addressing usability, barriers, and facilitators to use

Author, year Study design Risk of bias	HIE description Type of HIE Patient consent process	Evaluation data	Results
Mixed methods			
Bouhaddou, <i>et al.</i> , 2011 ⁷¹ Cross-sectional study of patient records, Consent; usage. Risk of bias: Not rated	NwHIN allows users to pull in data from other organizations. The VA and DoD used the VLER systems for eHealth exchange with private sector. Federated pull (query-based) model Transfer of records between integrated delivery systems; National query-based. Consent was opt-in.	Patient identifier and demographic data	Of 363 patients who opted in and provided valid authorization, 264 could be correlated; exchange of records between KP and VA 2-3 per week. Older patients were more likely to consent for HIE.
Byrne, <i>et al.</i> , 2014 ¹⁰¹ Cross-sectional study of patient records. Quantitative data on Veteran participation and provider usage, interviews with both. Risk of bias: Not rated	HIE between VA, DoD, non-federal care organizations. The Nationwide Health Information Network (NHIN). The VA and DoD used the Virtual Lifetime Electronic Record (VLER) systems for eHealth exchange with private sector. Federated pull (query-based) model Transfer of records between integrated delivery systems; National query-based. Consent was opt-in. .	Veterans' authorization preferences, system dashboard. 73 provider interviews, 50 veteran interviews.	-Used opt-in model for patients and 81% of veterans agreed that each patient has a choice -Matching of patients varied from 12-88% dependent on whether the exchange partner used social security number -None of the veterans interviewed were aware if their providers were using HIE, the user-interfaces at the sites face the provider not the patient -Providers increased usage after training on VLER system -Providers noted barriers of missing data, additional sign-on and need for better integration with workflow
Johnson, <i>et al.</i> , 2008 ⁸⁴ Quantitative review of audit-log files; qualitative analysis of feedback of system. Risk of bias: Not rated	MSeHA in Memphis, Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Consent was opt-out.	Audit logs, demographics of users, feedback from users	-MSeHA was used for 3% of all visits -The site with the highest usage had registrars looking up HIE data when patient arrived at the ED -The site that mostly serves pediatric patients used MSeHA the least vs. other sites

Author, year Study design Risk of bias	HIE description Type of HIE Patient consent process	Evaluation data	Results
Johnson, <i>et al.</i> , 2011 ¹⁰³ Population-based, cross-sectional quantitative audit data; Qualitative: semi-structured interviews and direct observations. Risk of bias: Not rated	MSeHA in Memphis Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Consent was opt-out.	Audit logs, feedback in system (12% of all patient visits with HIE), interviews, observations ED claims.	HIE access was higher where nurses and clerks involved and lowest where MD only access, patient opt-out rates were 1-3%.
Qualitative studies			
Campion, <i>et al.</i> , 2012 ⁵⁰ Survey of physician satisfaction with push vs. pull HIE Moderate risk of bias	HealthLink, Rochester New York RHIO. Direct exchange (push) of local lab and radiology results; query-based (pull) searching for lab and radiology results across greater Buffalo and Rochester area	Online survey responses from 112 of 584 invited physicians (19% response rate). Only 99 completed survey.	80% used push HIE and 53% used pull HIE. A greater proportion of MDs reported using push HIE always or most of the time (68%) compared to pull HIE (19%), (p=0.001). MDs more satisfied with push HIE than pull HIE (p<0.05).
Gadd, <i>et al.</i> , 2011 ⁷⁵ Survey of HIE use and usability Low risk of bias	MSeHA in Memphis Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Consent was opt-out.	Email survey responses from 165 of 237 health care professionals (70% response rate).	-3 usability factors were positively predictive of system usage: overall reactions (p<0.01), learning (p<0.05), and system functionality (p<0.01) -Users commented that HIE needs more tech support and could use more types of data
Unertl, Johnson and Lorenzi, 2012 ¹⁰⁴ Multi-site case study. Ethnographic qualitative study, direct observation, informal interviews during observation, formal semi-structured interviews with HIE users. Moderate risk of bias	MSeHA Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Consent was opt-out.	Observation (180 hours) in 6 ED and 8 ambulatory clinics, informal interviews during observation and 9 formal semi-structured interviews with physicians, nurses and IT management	-HIE workflow was modeled for each ED site and clinic -2 models emerged: physician-based and nurse-based

Author, year Study design Risk of bias	HIE description Type of HIE Patient consent process	Evaluation data	Results
Machan, Ammenwerth and Schabetsberger, 2006 ⁵⁴ Qualitative semi-structured, problem-centric interviews followed by cross-sectional survey on usage. Low/moderate risk of bias.	TILAK, HIE in Tyrol region of Austria. Transmission of discharge letters and clinical findings from hospitals to general practitioners. Direct exchange via email.	Interview data from 4 providers followed by cross-sectional survey of 104 of 242 (43%) providers on HIE use.	-Overall satisfaction positive for 66.4%, with 83.7% agreeing to receiving all reports electronically, 82.7% reporting less work for filing and archiving, and 78.8% agreeing it led to improved quality of care -Barriers were reported, e.g., reports not meeting physician's needs -One facilitator is automatic filing of HIE information in patient EHR
Massy-Westropp, <i>et al.</i> , 2005 ¹¹¹ Cross-sectional survey and 2 staff focus group sessions High risk of bias	HIE in Adelaide, South Australia linking a public teaching hospital, ED and aged home-based care community services organization.	Satisfaction survey responses from 55 of 132 nurses, clinicians and allied health staff.	Those who had embraced the use of the integration tools were significantly more likely to rate Integration higher than those who were not using it as often (p<0.001). In the discussion they estimated a 20% savings in staff time.
Messer, <i>et al.</i> , 2012 ¹¹³ Organizational readiness to change, needs assessment interviews and pre-post quantitative survey of HIV provider users Moderate risk of bias	North Carolina HIV information cooperative regional health information organization (CHIC RHIO). 1 large academic med center and 5 AIDS service organizations. Used CAREWare from HRSA. Federated, query-based exchange.	Interviews and assessment with 39 stakeholders; pre and post survey of 29 providers' satisfaction with HIE, relationships with other providers, barriers.	-Qualitative and quantitative approaches provided several "lessons learned" -It is important to establish clear understanding of privacy and data sharing among stakeholders -Initial concerns about confidentiality diminished over time as trust was built -Respondents noted it is important to manage expectations upfront -Clinic staff must use 2 systems the EHR and CAREWare which takes effort and increases errors -There was an unmet need for training for report generation
Myers, <i>et al.</i> , 2012 ¹¹⁷ Quantitative: emailed survey to current and intended users; qualitative: interviews with current HIE users during site visits Low risk of bias	5 HIEs that were part of the Information Technology Networks of Care Initiative that included Bronx-Lebanon Hospital Center, Duke university; hospitals, the city of Paterson, Louisiana State University Health Care Services Division, New York Presbyterian Hospital, St. Mary Medical Center Foundation. Query-based.	Interviews and web-based survey with case managers, providers and non-clinicians on usefulness and ease of use. 62 of 102 responded (62%)	-Mean composite for ease of use was high (3.9 of 5.0) and no difference by role -Mean composite for usefulness was also high (4.0 of 5.0) and no differences by role -Qualitative: adoption of the HIEs and perceptions of its use and usefulness varied by occupational role of the patient-care team. Also noticed that case workers outside the clinic used the HIE routinely. Those within clinics used HIE sporadically.
Hincapie, <i>et al.</i> , 2011 ¹⁰⁹ Focus groups of physicians Moderate risk of bias	AMIE based on MA-Share created for the NHIN that is a federated query-based exchange model. Medication history, lab test results, and discharge summaries.	Focus group meetings of 29 physicians on HIE quality of care, workflow, cost	Benefits included identification of "doctor shopping", avoiding duplicate testing, and increased efficiency for gathering information; disadvantage was limited availability of data.

Author, year Study design Risk of bias	HIE description Type of HIE Patient consent process	Evaluation data	Results
McCullough, <i>et al.</i> , 2014 ¹² Key informant interviews with stakeholders at practices and health centers Low risk of bias	2 states: California, Minnesota. California: Collaborate HIE system, a Query-based exchange from three hospitals, 90 providers, and laboratories. Minnesota: CentraHealth exchange between Federally Qualified health Centers and hospitals. <i>This system was in implementation at time of study.</i>	24 interviews	Identified barriers: Lack of well-functioning area-level exchange, challenge achieving a critical mass of users, need strong relationships with exchange partners, incompatible Health IT used, data ownership and provider liability concerns about who sees the data, can't find data on patients. Identified benefits: Improved productivity at initial visit, improved completeness of records, avoidance of duplicative services of patient financial risk Improved non-visit consults
Rudin, <i>et al.</i> , 2011 ¹⁵ 20 interviews with clinician users, HIE staff and administrators Low risk of bias	Massachusetts eHealth Collaborative. All non-text portions of medical record. Could link directly from the EHR to existing HIE. Query-based exchange. Consent was opt-in.	Interviews of 15 clinician users, 2 HIE staff, and 3 administrators	-Motivators were belief in improved quality of care, time savings, and reduced need to answer questions. -Motivation was moderated by missing data, workflow issues, and usability issues (too many clicks required to get to information). -Missing data was attributed contributing providers not "locking their notes" on their EHR.
Thorn, Carter and Bailey, 2014 ¹⁶ Interviews with ED physicians using HIE Low/moderate risk of bias	HIE name not explicitly stated but may be MidSouth eHealth Alliance (MSeHA). Decentralized, query-based exchange. Consent was opt-out.	Individual unstructured interviews with 15 ED physicians	Barrier themes 1. Trouble accessing system, acuity of patient or history not available, team members' inability to access. 2. HIE use affected decisions only sometimes, for specific cases (e.g. drug seekers). 3. Access challenges, separate login, variability in data being pertinent, absence of data types or data on specific patients, user design flaws, and lack of technical support. 4. Barriers to usage also included continued practice of defensive medicine, desire for autonomy, changing the culture, belief that HIE does not alter decisions, health system competition, and reduced revenue, workflow disruption.
Kierkegaard, Kaushal and Vest, 2014 ¹⁰ Multi-site case study. Qualitative, interviews with users and non-users of HIE. Moderate risk of bias.	3 RHIO sites in New York: 2 federated models, 1 centralized model. Query-based but also provided direct exchange of CCD	2 day site visits, onsite and telephone interviews with HIE users and non users, observations of workflow	-MDs had low tolerance for search failures -Where clerks were not trained or supported, fewer patients consented -MDs often delegated the HIE task -Login process perceived as a burden and system was slow.

Author, year Study design Risk of bias	HIE description Type of HIE Patient consent process	Evaluation data	Results
Ozkaynak and Brennan, 2013 ¹¹⁴ Multi-site case study. Direct observation, informal interviews during observation, formal semi-structured interviews with HIE users. Moderate risk of bias	3 ED sites accessing the EDLinking system in Madison, Wisconsin	210 hours direct observations, varied across shifts, in 5 rounds, by 1 or 2 observers with informal conversations to followup, plus 13 open ended HIE interviews.	-The ED providers only used the HIE for 5% of visits -It was used primarily for patients in chronic pain to detect drug-seeking behavior. This information was then used as support to confirm or confront patients who may be abusing the system.

Abbreviations: AMIE = Arizona Medical Information Exchange; CCD = Continuity of Care Documents; CHIC = Carolina HIV Information Cooperative; DoD = The Department of Defense; e = electronic; ED = emergency department; e.g. = for example; EHR = electronic health record; HIE = health information exchange; HRSA = Health Resources and Services Administration; IT = information technology; KP = Kaiser Permanente; KQ = Key Question; MD = medical doctor; MN = Minnesota; MSeHA = Mid-South eHealth Alliance; NA = not available; NwHIN = The Nationwide Health Information Network; RHIO = regional health information organization; St. = Saint; TILAK = Tiroler Landeskrankenanstalten; VA = The Department of Veterans Affairs; VLER = Virtual Lifetime Electronic Record; vs. = versus.

Key Question 7. What facilitators and barriers impact implementation of HIE?

Key Question 8. What factors influence sustainability of HIE?

Key Points

- There is a sizable body of research that explores the facilitators and barriers to implementation and factors that affect the sustainability of HIE (45 studies).
- This literature identifies several characteristics of HIE itself or its components (internal factors) but identifies fewer policy and external environment influences that affect implementation. The most commonly identified facilitators were general organizational characteristics such as leadership while the most frequently cited barriers were disincentives such as financial viability.
- For sustainability the most frequently cited barrier was competition while the expected outcomes from HIE and the selection of HIE functions most likely to have financial benefits were identified as two key positive influences.

Detailed Synthesis

Implementation involves identifying new practices or technologies; making the decision to incorporate them into workflow and processes; and taking the actions necessary to prepare for and then initiate adoption of change. Sustainability is essentially the ongoing maintenance of what was implemented, but also includes the idea that the practice or technology that was implemented must evolve to continue to meet the needs of the organization. Approaches to understanding implementation and sustainability are rooted in consideration of the fit between an organization and the practice or technology as well as the external and internal factors that either facilitate or act as barriers to the change. In the case of HIE, health care organizations must consider first whether, and then how, to participate in HIE (implementation). Once HIE is established the focus shifts to how to maintain, improve, and grow the systems (sustainability).

We identified 45 studies that addressed implementation and/or sustainability (**Appendix G**). The included studies were all published in the past 8 years (2006 to 2014). Five studies assess HIE in countries other than the United States, nine were based on U.S. national surveys or data, seven covered multiple sites in the United States, but the most common were 25 studies that covered single state or regional HIEs. Six of the studies were about New York, with five about statewide efforts or several RHIOs and one about New York City. Three were about HIEs in California, but each study was about a different regional HIE. No other state or metropolitan region was the subject of more than two studies.

Given the focus of these Key Questions, it is not surprising that most studies were qualitative. Thirteen studies reported the results of qualitative analysis of data from interviews^{35,87,118-128} while an additional 11 also applied qualitative methods to data from multiple sources that all included interviews as well as focus groups, document analysis, and observations.^{71,106,113,129-136} Others were narrative descriptions of processes or

reporting based on system logs or similar computer tracking. Five studies used mixed methods.^{74,99,101,107,137}

The remaining 16 studies used quantitative data with three reporting descriptive statistics of systems data^{40,85,138} and six descriptive statistics of survey responses.^{22,73,76,139-141} One study employed econometric modeling¹⁴² and six used multivariate analyses methods^{36,93,143-146} with HIE operational status or HIE use as the outcome (5 of 7) while one assessed saving and another the receipt of a second round of grant funding. One study combined a secondary analysis of the literature with ranking of by experts in order to evaluate drivers of financial savings.¹⁴³

Thirty-seven studies identified one or more facilitator or barrier to implementation while 14 studies reported factors related to sustainability. We grouped the facilitators into eight categories and the barriers into seven categories created based on our interpretation of their similarities. In **Tables 9 and 10** the specific factors included in each category are listed below the category in the first column and the studies that report this factor related to implementation or sustainability are cited in the second and third column respectively.

Implementation

Facilitators

Seven of the eight categories of facilitators for implementation identified in the literature (below) are predominately ‘internal’ factors, concerned with the characteristics of the HIE or its components, while only one category, external policy, addresses the environment for the HIE.

General structural characteristics. These include leadership,^{35,130,133,137} prior experience with or readiness for IT projects,^{113,129} pre existing membership in a network,¹⁴⁶ or trust and solidarity among practices participating in HIE. One evaluation of HIE efforts concluded that, “having IT initiatives underway prior to receiving... funding contributed substantially to the states’ readiness and subsequent implementation progress.”¹²⁹

HIE specific structures. This category includes finding from four studies and specific factors included governance,³⁵ and participatory approaches.^{40,107,124} Examples include findings that involving users in development was key to implementation¹²⁴ and that a participatory process and shared decision making permitted the HIE to address different values held by participants related to balancing individual rights and public health.¹⁰⁷

Orientation shift in the HIE organization. This is a category that could also be called mission or change in ideology. Two studies found that implementation depended on a shift from competition to collaboration,¹³⁵ or from ownership of data to continuity of care that included realizing the value of external information.¹³⁶

Design characteristics. Cited as facilitator for implementation in five studies. Studies found that a design that reflects an understanding of work flow,¹²⁴ and designs with smaller scale or more limited scope were more likely to be implemented.^{128,140} The

architecture and adaptability of information systems were cited as important design characteristics by two studies^{122,128} with one researcher explaining, “Our findings suggest that communities embarking on HIE initiatives would do well to examine how particular HIE technical architectures map to their objectives, local context, existing relationships, sustainability plans, and vision of both present and possible future needs .”¹²²

Key functions of HIE. This is a category of functions that may seem obvious but that are essential. Four studies reported that HIE systems needed to be set up so that use became part of care routines, so that the burden and time required of staff was minimized and so that useful data was provided.^{74,99,101,128} One study concluded: “Implementation outcomes...were shaped substantially by the degree of attention dedicated to reworking procedures and practices so that HIE usage became routine.”¹²⁸ Another study highlighted that addressing issues related to providing better quality data and integration into work flow allowed successful system-wide deployment.¹⁰¹ However, the capacity for advanced use, that is HIE that provides new tools or information may be an important facilitator as HIE evolves. One study cited the example of HIE providing the foundation for develop of system that altered providers to important patient events leading to both improvements in quality of care and contributing to organization goals such as medical home certification.¹¹⁹

Implementation support. This is needed according to the results of four studies includes the technical assistance and training infrastructure,^{99,125} the ability to do extensive testing for data quality,¹³⁵ as well as a comprehensive strategy for the HIE and its implementation.¹²⁷

Expected outcomes. Two studies reported that specific expected outcomes were key to implementation. These included public awareness of the HIE,¹³² and link to a community need.¹³¹

External policy. Federal and State laws and mandates,^{74,142} as well as grants¹²⁹ were identified as facilitators when they promoted, required, or funded HIE director or foundational components such as EHRs.

Barriers

Barriers to HIE implementation cited in the research (below) are not simply the inverse of the facilitators. While there is some overlap in the categories, the barriers cited include more external, environmental factors. The seven categories of barriers are included in **Table 11**.

External policy. This is the one category of barriers that corresponds most directly to a category of facilitators. While federal and state laws and funding and grants were seen as facilitators for HIE implementation, changes in federal and policy,¹³³ and both the uncertainty and the timelines for funding.^{119,137}

Disincentives. This is a broad category and the largest, including 15 studies. Four studies report that competition for patients and the difficulty making the business case for HIE are important barriers,^{93,118,141,146} and five additional studies more specifically cite the costs of HIE and the lack of financial viability.^{22,74,125,129,139} In states with mature HIEs, where presumably the infrastructure was in place, not participants cited costs and a lack of understanding of the value proposition as the major barrier to participation.¹³⁹ Three studies identified the fact that the organizations that invest in HIE are not always the ones that benefit (e.g., hospitals invest in HIE but do not necessarily realize the savings when duplicate tests or admissions are avoided).^{121,129,146} Two additional studies cited insufficient resources.^{73,76} In addition to financial and resource concerns, four studies identified concerns about data misuse, ability to protect privacy and ethic issues related to sharing data.^{107,118,121,132}

Structural characteristics. This is a category of barriers that includes some parallels in the facilitators—leadership can promote HIE, but lack of leadership or effective communication from management can be important barriers according to two studies.^{74,137} While being in a network might facilitate HIE, one study concluded that hospitals that are part of larger systems are less likely to participate in HIE, perhaps because patients stay in the system and there is less need for external data.¹⁴⁵ Another identified barrier is the mismatch between the geographic coverage of the HIE and the service areas for patients, as would be the case for a hospital with a service area that crosses state lines and a state-based HIE.¹³²

Technology. The second most frequently cited (9 studies) category of barriers to implementation were issues related to technology. More specifically these barriers relate to the technological environment. Two studies cited the lack of standards or differences in standards across organizations.^{76,138} Similarly three studies reported that interoperability across systems was an issue,^{74,118,141} while three more studies specifically mentioned difficulties related to EHR interfaces.^{119,125,135} One study was less circumspect in citing problems with vendors and reporting that “the most significant barriers ... were largely due to a long and arduous process of collaborating with commercial entities involved in technology design and delivery.”⁴⁰

Lack of necessary components. This was presented as a barrier in five studies. Four studies reported that participants or providers were not sufficiently engaged in implementation of the HIE or were not aware of its value.^{73,129,135,139} One study emphasized that physician engagement was important by pointing out that physicians are the primary source of care data and suggested that for this reason their engagement is the primary determinant of HIE success.¹³⁵ One study focused on the challenges in securing data sharing agreements as a barrier to implementation.¹¹⁹

Fit. This is short hand for the correspondence between an innovation and the potential adopting organizations. Lack of fit is barrier that may not be apparent when the innovation is assessed out of context. Two studies found that HIE implementation was deterred when organizations or departments were unable or unwilling to integrate HIE

into work processes.^{125,134} Another instance where lack of fit is problematic is when expectations are not met. Two studies reported that expectation for the data in terms of timeliness and completeness were barriers to implementation.^{85,120} One additional study underlined the fact that timelines were not realistic particularly in cases where the technology was to be integrated into quality improvement activities.¹¹⁹

User interface and functionality. Eight studies cited specific user interface and functionality problems as barriers to implementation. These included lacking the technology and human resources needed to adapt the organization's software and processes for HIE,¹³⁹ and the need for training and expertise.^{118,137} Two studies reported that user problems as fundamental as forgotten logons¹²⁰ and the technical performance of network connections hindered implementation.¹⁰¹ One study reported corrupt data as a barrier to HIE,¹³⁸ while another reported tests that identified that the ability to match patients across systems was limited.⁷¹ One study of an advanced application of a system to generate alerts based on HIE data stalled when the providers to notify about a patient's events could not be identified.⁸⁵

Subgroup Group Differences

During our review we attempted to abstract data from the included studies that would allow us to determine if the barriers and facilitators to implementation varied by type of HIE, health care settings and systems or IT system characteristics. Most publications did not include this information and we did not identify any differences.

We also considered that implementation might change over time as HIE becomes more common and as new HIE efforts could benefit from the experience of early adapters. At this time we do not see any notable changes, but this may be to the relatively short time period (less than a decade) covered by the included studies. While the hardware and software that make HIE possible have changed significantly in a less than a decade, organizational change and clinical practice patterns have historically changed more slowly.

Sustainability

In making a distinction and summarizing the factors identified in the 14 studies that considered sustainability separately, we placed studies according to what the researchers/authors reported as their focus and we accepted their definitions and/or measures.^{22,36,87,106,121,123,126,131,132,140,142-145} As HIE and health IT mature, a definition of successful sustainability may be developed and the evidence could then be reanalyzed incorporating such a definition.

The factors that have been found to influence the sustainability of HIE fit into the categories created to summarize the facilitators and barrier for implementation, and in some cases it can be difficult to make a distinction. This is in part because sustainability is still a future goal rather than for all but the very early HIEs.

We present the sustainability factors under the most appropriate category on **Tables 10 and 11**, but added rows for specific factors when they differ from those identified in studies of implementation.

Eight included studies identified factors that are positive influences on sustainability. These included having an HIE lead by a health information as opposed to a health care organization,¹⁴⁴ and marketing the HIE to patients.¹⁰⁶ Sustainability was also linked to how an HIE incorporated a community needs assessment,¹⁴⁴ and if it selected functions likely to financially benefit the participants.^{121,143} One study suggested that HIEs with advanced functions such as providing decision support are more sustainable.¹⁴³ Achieving important expected outcomes such as improved quality of care,¹²⁶ and realizing saving that exceed the costs of the HIE are understandably important.³⁶ One study reported that laws and mandates could promote sustainability as well as implementation of HIE.

However, laws and mandates, particularly changes in these were also one of the reported negative influences on sustainability.¹²³ Four studies found that competition and a difficult business case for HIE were challenges to sustainability.^{87,132,140,145} Three structural characteristics of HIE were also identified. These included the mismatch between the HIE geographic coverage and where patients receive services;⁸⁷ issues related to governance and trust among the HIE collaborators;^{87,126} while one study found that HIEs that focused on long term care organizations were less likely to be sustainable.¹⁴⁴ Lack of standards was the only factor directly related to the technology for HIE reported among the negative influences and it was reported in only one study.¹²³ Lack of sufficient engage of participants and providers was also reported in one study.¹³¹

While there is less evidence related to sustainability to report in this review than for implementation, the studies to date suggest it is the more complex of two very complex and related topics. One researcher suggested this complexity when making the assessment that this issue for HIE sustainability are sociological not technological,⁸⁷ while another suggested sustainability may become less a matter of availability of funds and more one of trust and responsible stewardship.¹⁰⁶

Table 10. Facilitators to implementation and sustainability of HIE

	Implementation facilitator	Sustainability positive influences
	# of studies reporting	# of studies reporting
General structure/organization	8	
Leadership	4 ^{35,130,133,137}	
Prior IT initiatives or IT readiness	2 ^{113,129}	
Network membership	1 ¹⁴⁶	
Trust and solidarity	1 ¹²⁵	
HIE specific structure	4	2
Participatory approach	3 ^{40,107,124}	
Governance	1 ³⁵	
HIE lead by Health Information Organization		1 ¹⁴⁴
Community needs assessment		1 ¹⁴⁴
Marketing to patients		1 ¹⁰⁶
Orientation shift	2	
From competitive to collaboration	1 ¹³⁵	
From ownership of data to continuity of care	1 ¹³⁶	
To valuing contribution of external information	1 ¹³⁶	
Design characteristics	5	2
Information system architecture/adaptability	2 ^{122,128}	
Smaller scale/limited scope	2 ^{128,140}	
Reflect understand of services and work flow	1 ¹²⁴	
Select function likely to have financial benefit		2 ^{121,143}
Key functions	5	1
Make use routine/minimize burden and time/provide useful data	4 ^{74,99,101,128}	
Advance use (decision support; medical home functions)	1 ¹¹⁹	1 ¹⁴³
Implementation support	4	
Comprehensive strategy	1 ¹²⁷	
Extensive testing for data quality assurance	1 ¹³⁵	
Technical assistance/training/change management	2 ^{99,125}	
Expected outcomes	2	2
Public awareness	1 ¹³²	
Link to community need (public health use)	1 ¹³¹	
Savings exceed costs		1 ³⁶
Quality of care		1 ¹²⁶
External policy	3	1
Laws and mandates	2 ^{74,142}	1 ¹⁴²
Federal and state grants	1 ¹²⁹	

Abbreviations: HIE= health information exchange; IT= information technology.

Table 11. Barriers to implementation and sustainability of HIE

	Implementation barriers	Sustainability negative influences
	# of studies reporting	# of studies reporting
External policy	3	1
Laws and regulations		1 ¹²³
Changes in external (federal, state) policy	1 ¹³³	
Funding uncertainty and timelines	2 ^{119,137}	
Disincentives	15	4
Competition/difficult business case	4 ^{93,118,141,146}	4 ^{87,132,140,145}
Costs/financial viability	5 ^{68,74,125,129,139}	
Organizations that invests does not benefit	3 ^{121,129,146}	
Resources (funding and time)	2 ^{73,76}	
Concerns about data misuse, privacy, or ethics	4 ^{107,118,121,132}	
Structure	4	3
Geographic coverage mismatch with service areas	1 ¹³²	1 ⁸⁷
Lack of leadership and management communication	2 ^{4,137}	
Larger hospital systems (less need for external exchange)	1 ¹⁴⁵	
Focus on long term care		1 ¹⁴⁴
Governance/trust		2 ^{87,126}
Technology	9	1
Lack or differences in standards	2 ^{76,138}	1 ¹²³
EHR interface	3 ^{119,125,135}	
Interoperability across systems	3 ^{4,118,141}	
Problems with vendors	1 ⁴⁰	
Lack of necessary components	5	1
Participant/provider engagement, awareness of value	4 ^{73,129,135,139}	1 ¹³¹
Securing data sharing agreements	1 ¹¹⁹	
Fit	5	
Inability or willingness to integrate into work processes	2 ^{125,134}	
Lack of enough time for development and integration into Quality Improvement	1 ¹¹⁹	
Failure to meet expectations that data needs will be timely, complete and meet expectations.	2 ^{85,120}	
User interface and functionality	8	
Tech and HR resources to adapt software and processes	1 ¹³⁹	
Need for training and expertise	2 ^{118,137}	
Corrupt data	1 ¹³⁸	
User interface and technical performance	2 ^{101,120}	
Ability to match patients	1 ⁷¹	
Difficulty identifying provider to get alerts generated from HIE	1 ⁸⁵	

Abbreviations: EHR= electronic health record; HIE= health information exchange; HR = human resources; IT= information technology.

Discussion

Key Findings

- We found no studies of health information exchange (HIE) that reported the impact on clinical outcomes or identified harms.
- The majority of the included studies reported that HIE improved resource use by reducing lab tests, imaging, or hospital admissions and improved quality of care, but the strength of evidence is low for all outcomes.
- Studies found that HIE was used by between 30 and 58 percent of hospitals and, 38 percent of office-based physicians in 2012, while use remains low in long-term care settings.
- Within organizations, studies that looked at the number of users or the number of visits in which the HIE is used found generally very low rates of use.
- Studies did not link usability of HIE to effectiveness but they did link it to use.
- The most commonly cited barriers to HIE use were incomplete patient information, inefficient workflow, and poorly designed interface and update features.
- While several studies provide information on both external environmental and internal factors and internal organizational characteristics and that affect implementation and sustainability, it is not possible to assess their comparative impact on the success of HIE.

Key findings are summarized in **Table 12**.

Table 12. Summary of evidence

Topic # of included Studies Type	Main findings	Primary limitations of the evidence
Key Questions 1-3 Effectiveness 31; 28 observational 2 RCTs	Most studies report positive impacts but the strength of evidence is low for all outcomes. No evidence on harms.	Studies are of a small number of the functioning HIEs, with similarity to unstudied ones unknown, possibly limited generalizability. Studies look at extremely limited outcomes compared to the intended scope of the impact of HIE
Key Question 4 Use of HIE 49; Surveys -18 Retrospective database -9 Mixed methods-5 Focus Groups-2 Time-motion-1 Geo-Coding-1	Proportion of hospitals and ambulatory care practices that have adopted HIE is increasing. Currently, proportion of clinicians using HIE and proportion of patients or episodes associated with HIE use are generally low.	While there are relatively high quality national and regional surveys and reports that are tracking the expansion of HIE among health care organizations, there is not a corresponding comprehensive effort to track changes in rates of use within organizations.
Key Questions 5 & 6 Usability and factors in use	Three most commonly cited barriers to HIE use were: incomplete patient information (8 studies); inefficient	Studies of usability did not relate it to effectiveness and do not permit comparisons across settings or type of HIE

Topic # of included Studies Type	Main findings	Primary limitations of the evidence
17; Qualitative-13 Mixed Methodss-4	workflow (6 studies); poorly designed interface and update features (6 studies).	Studies had limitations such as incomplete reporting on sampling, low response rates or selection of a narrow setting or patient population which minimize applicability.
Key Questions 7 & 8 Implementation and sustainability 45; Interviews-13 Qualitative Analysis of several data sources-11 Mixed methods-5 Quantitative-16	Most facilitators of implementation are characteristics of the HIE or the internal organizational environment. Many barriers to implementation are external, environmental factors. Factors related to sustainability overlap with those identified for implementation.	Studies do not allow comparison of the impact of different barrier and facilitators. The definition and appropriate measure of sustainability are not yet clear.

Abbreviations: HIE= health information exchange; RCT- randomized controlled trial

Strength of Evidence

Assessing the overall strength of the evidence for this review is complex, given 1) the very broad scope of the review; 2) the large variety of effects and outcomes examined by investigators; 3) the diverse types of evidence and study designs; 4) the differing units of analysis and intervention (from episodes of care, to individual clinicians or patients, to hospitals or clinics, to health systems, to regional or statewide efforts); 5) the multiple contexts of care, from acute care in emergency department (ED) visits to public health reporting and analysis; 6) the variety of technical implementations, even within the broad categories of query-based and directed HIE; and 7) the likelihood of reporting bias, expected to be in the direction of positive findings, with likely under reporting of failed or ineffective HIE. In view of these challenges, we elected to explicitly and systematically assess the risk of bias and strength of evidence only for studies addressing the effectiveness and harms of HIE, our Key Questions 1, 2, and 3.

These limitations notwithstanding, a collection of low strength evidence supports the notion that HIE can reduce near term (e.g. ED) utilization of health services such as ordering of laboratory tests and imaging studies. It is unlikely that additional studies of the kind included in this review will alter the overall conclusion that HIE can reduce laboratory and imaging tests associated with episodes of care without broadening their scope and using more rigorous designs. Though the preponderance of evidence supports positive effects in terms of reduced resource use and improved quality of care, it is entirely possible that focused studies with stronger study designs and more comprehensive assessment of utilization or clinical outcomes might reach a different conclusion.

With respect to cost, we did not identify any studies that employed systematic and comprehensive economic analysis. Although some of the studies we included projected or estimated cost savings based on measured changes in utilization or perceptions of clinicians, there were no studies that explicitly measured costs and assessed economic impact in a comprehensive fashion. It is fair to say, then, that there is insufficient evidence to reach conclusions on the economic impact of HIE.

As stated previously, we found no studies explicitly addressing patient specific clinical outcomes such as morbidity, mortality, or functional status and hence the body of evidence is insufficient to determine whether HIE has an impact on patient outcomes.

Findings in Relationship to What is Already Known

The findings of this review add to the substantial, albeit methodologically challenging, evidence base relating to health information technology (IT) generally and HIE in particular. A series of comprehensive and systematic reviews of health IT published over the last decade, including three from a single Evidence-based Practice Center (EPC)^{5,6,8} and one from the Office of the National Coordinator⁷ confronted similar challenges in the diversity and breadth of settings, interventions, and outcomes. Overall, these reviews found that the preponderance of studies of health IT reported generally positive or "mixed-positive" effects, but with caveats about the likelihood of publication bias, methodological limitations of the studies, and concentration of studies coming from a relatively small number of institutions.

The present systematic review of HIE is most directly comparable to another systematic review of HIE conducted simultaneously by Rudin and colleagues.²⁶ These two systematic reviews took similar approaches but differed in that the present study was more inclusive overall, addressing similar but slightly broader research questions, searching additional literature databases, and employing more inclusive selection strategies in terms of HIE function and geographic location. As a result, the two reviews are based on a relatively comparable evidence base. The present review includes a total of 115 studies, the Rudin *et al.* review includes 85, with only 55 being included in both reviews (we assessed the Rudin *et al.* review for references and included in ours any that met our inclusion criteria).

The main point to be made about the comparison between these two reviews is that two review groups have now independently searched for and assessed the evidence on the effectiveness of HIE and are in agreement on the main conclusions. This raises somewhat the level of confidence in the conclusions in that the two reviews represent independent replication of one another's work, albeit with the same rather significant limitations in the body of evidence on which the conclusions are based.

The main differences between the two systematic reviews concern their scope. Rudin *et al.* explicitly excluded studies of HIE used for public health purposes and studies of HIE outside the United States, while the present review included these categories. The present review explicitly included studies of usability and studies of barriers and facilitators of both implementation and use, while Rudin *et al.* did not explicitly examine usability. The result is we examined a more diverse collection of studies, especially with respect to usability and use of HIE, but came to largely similar conclusions, though we found that the additional evidence was not of high enough quality to change the conclusions.

The problem of overlap between systematic reviews is an important one, one which has recently been addressed in the methods guides of the Cochrane Collaboration,^{147,148} and the Agency for Healthcare Research and Quality EPC program.¹⁴⁹ With large numbers of systematic reviews being conducted there is inevitable overlap when two reviews are based on the same body of evidence. It must be kept in mind when this occurs that additional reviews on the subject do not indicate more evidence on the question, only more thorough (when independent) examination of the same evidence.

Applicability

Are the effects reported on in this review, limited as they are, likely to be observed when applied under 'real world' conditions in health systems, hospitals, and clinics in the United States? The greatest confidence in the applicability of these findings comes from the breadth of settings - geographic, organizational, and technical - from which they are derived. That is to say, for the most part, it can be expected 1) that near-term resource utilization in the form of laboratory and imaging test ordering is likely to be reduced when effective HIE capabilities are deployed, while the effect on other utilization and quality indicators is harder to predict; 2) that use of HIE will be highly dependent on the context of use, perceived value of the information to the patient care task, and the degree of integration into clinical workflows, including potential delegation by clinicians to other members of the health care team depending on the setting; and 3) that hospital and health system implementation and participation in HIE will be driven by the perceived value and return on investment, alignment with organizational goals, internal capacity to address technical challenges, and the presence of local and national external financial, regulatory, and policy constraints.

On the other hand, there are limitations to the applicability of the findings (beyond limitations to the internal validity already mentioned) having to do with three main concerns: 1) concentration of evidence from a relatively small number of sources; 2) use of internally developed and refined health IT systems compared with local instances of commercial systems; and 3) the exceptionally broad variety of systems, contexts, and purposes of HIE reported in the studies included in this review.

First, the concern that the bulk of the evidence about health IT impact arises out of a relatively small number of centers has been raised before.⁵ These centers have been referred to as "health IT leaders," which typically are large academic medical centers with internally developed health IT systems, implemented incrementally, and refined over a long period of time. The nature of the health IT systems is in each case unique (being locally developed), and more importantly it is difficult to separate the effects of the health IT from the confounding influences of the health system itself. Whether findings from these systems can be generalized to the very different context of health system and hospital implementations of commercially developed systems over shorter periods of time with less internal development and implementation infrastructure has been called into question.⁵ This "health IT leader" effect appears to be reduced in more recent updates to the 2006 systematic review by Chaudhry *et al.* but the issue remains important.^{6,8} In the present review of HIE the concentration of evidence phenomenon is also present, with large numbers of published studies emanating from relatively few areas, this time regional implementation programs rather than academic health centers, such as Texas, New York, and the MidSouth e-Health Alliance.

Second, separate from the "health IT leader" concern - which has to do with the organizational capacity, resources, and mission of these centers - is the issue of internally developed systems compared with commercially developed systems. Though no implementation is truly "off the shelf" because of customization of local instances of commercial systems, the overall model of health IT purchase and installation is quite different from that of incremental internal development, implementation, and refinement, such as one sees in systems such as the Veterans Affairs or the aforementioned "health IT leader" systems.

Third and most important in terms of limiting the applicability of these findings about HIE to "real-world" use is the exceptionally wide variety of systems, purposes, contexts of use, and

outcomes examined. To address the Key Questions of this systematic review, highly diverse evidence has been combined to answer general questions about the overall effectiveness of HIE for various outcomes. However, to predict whether specific implementations of HIE in specific health care contexts will have favorable impacts on specific desired outcomes is not possible from this review and in most cases would not be possible from comparison with individual studies because a) it is unlikely that studies with low risk of bias have been published for most such specific questions, and b) in almost all cases these are complex interventions which are incompletely specified, with insufficient detail to draw strong meaningful inferences.¹⁵⁰

Limitations of the Evidence Base

The very significant limitations of the evidence base, that is, the individual studies included in this review, have been raised in previous systematic reviews of health IT,^{5,6,8} and of HIE.²⁶ Although increasing in number, the relative proportion of well conducted studies with rigorous designs remains small, and we know from experience in other domains, such as hormone replacement therapy, that even a very large number of well conducted observational studies may be found to have misled us when results of rigorous experiments become available.¹⁵¹ In view of this fact, one must continue to proceed with caution when interpreting and applying the results of observational studies, even well conducted ones.

Beyond this, there are three primary concerns about the limitations of the available evidence on the impact of HIE (and health IT generally): suitability of study design, execution of the studies, and complexity of the interventions with implications for interpretation and for generalizability.

First, the evidence in this area addresses a wide variety of questions covering diverse domains beyond medical science from computer science, human factors, sociology, organization and management and other disciplines. This broad array of questions calls for an equally diverse range of study designs. Studies of usability and use require usability engineering methods, studies of individual behavior call for methods from anthropology and behavioral sciences, studies of organizational change warrant methods drawn from management and systems science, while studies of population effects call for the methods of epidemiologists. As Sackett and Wennberg noted, “the question being asked determines the appropriate research architecture, strategy, and tactics to be used—not tradition, authority, experts, paradigms, or schools of thought.”¹⁵² A significant limitation of this literature, with its breadth of research questions, is the limited toolbox often drawn upon to answer them.

The second main area of limitation is in execution of the studies. Even when strong study designs are chosen, their execution may be lacking, whether in sampling strategies, measurement methods, or analytic approaches. The unit of analysis problem is but one example. Interventions carried out at the level of the health system, hospital, or clinic may be analyzed at the level of the patient or episode, without controlling for variation at these multiple levels. Incomplete measurement is another: for example where ED test ordering is measured in isolation, ignoring the possibility that the same test might later be ordered in another setting such as urgent care, primary care, or in hospital.

The third main area has to do with the complexity of interventions, where the HIE or other health IT system itself is necessarily only part of a more complex intervention. The complexity of interventions to change the behavior of clinicians or others in the health systems studied requires more thorough specification, both in order to adjust for confounders and in order to

make sense out of how to apply interventions elsewhere. Others have documented the inadequacy of specification of the details of complex interventions and called for a more systematic and thorough reporting.^{150,153}

Future Research Needs

Given the limited conclusions that can be reached after review of so much published literature on the effects, use, sustainability, and barriers to implementation and use of HIE, what are the implications for future research? Recognizing that HIE, like health IT in general, will almost certainly undergo increasingly widespread implementation in the future, the first aim of researchers should be to shift the emphasis from *whether* HIE systems should be implemented to specifically *how* they should be implemented. The question to be answered is not “Does HIE have positive effects?” but rather “How can HIE be implemented in order to result in the greatest benefit for patients, clinicians, and health systems with the least cost and harm?”

The second aim of researchers on HIE should be to develop greater focus and clarity about the level at which interventions are operating and the types and levels at which outcomes are measured. The outcomes of interest and the factors influencing them may be quite different at different levels of analysis, from specific systems or functionalities of HIE; to individual patients, providers, or episodes of care; to health care units such as the ED, primary care practice, or hospital ward; to institutions such as hospitals; to aggregates such as health systems; or broader regional multi-organization entities or regions. Combining or confusing these levels of intervention and levels of analysis only increase the challenges for those who conduct the research and for those who wish to interpret and apply it.

To help achieve an improved focus and clarity, a more formal analytic framework and taxonomy is needed. An example of such a framework that could be usefully applied in this area is Rasmussen’s socio-technical hierarchy, which specifies the multiple levels at which analysis may take place in a complex sociotechnical system.¹⁵⁴ Similarly, a formal taxonomy for implementation of complex interventions has been proposed which would enable more complete and useful specification of interventions to allow better analysis, interpretation, and application.^{150,155}

The third step researchers can take to improve the evidence base for implementation of HIE is to broaden the methodologic toolbox applied to these questions. As indicated above, the study approach and architecture must be suited to the question being asked, employing methods from usability engineering, behavioral sciences, systems engineering and organizational sciences, depending on the question being addressed. These would include methods used in engineering and quality improvement, as well as in the study of complex adaptive systems. In epidemiology it has been proposed that health and health care can be fruitfully studied as complex adaptive systems, which require “different methods from the usual epidemiological techniques.”¹⁵⁶ Examples include infectious disease epidemiology, smoking,¹⁵⁶ and obesity.¹⁵⁷ Because “(i) factors at multiple levels, including biological, behavioural and group levels may influence health and disease, and (ii) ... the interrelation among these factors often includes dynamic feedback and changes over time,” new approaches are needed to complement the classic methods of clinical trials which are frequently unsuitable for complex interventions in organizational contexts.

Conclusions

The full impact of HIE on clinical outcomes and potential harms is inadequately studied, although evidence provides some support for benefit in reducing use of some specific resources and achieving improvements in quality of care measures. Use of HIE has risen over time and is highest in hospitals and lowest in long-term care settings. However, use of HIE within organizations that offer it is still low. Barriers to HIE use include incomplete patient information, inefficient workflow, and poorly designed interface and update features, but factors affecting implementation and sustainability remain unclear. To advance our understanding of HIE, future studies need to address comprehensive questions, use more rigorous designs, and be part of a coordinated, systematic approach to studying HIE.

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Abbreviations and Acronyms

AHA	American Hospital Association
AHRQ	Agency for Healthcare Research and Quality
CCD	Continuity of Care Documents
CHIC	Carolina HIV Information Cooperative
CI	confidence interval
CT	computed tomography
DoD	Department of Defense
ED	emergency department
eGEMS	Generating Evidence and Methods to improve patient outcomes
EHR	electronic health record
EPC	Evidence-based Practice Center
HEAL-NY	Health Care Efficiency and Affordability Law for New Yorkers Capital Grant Program
HIE	health information exchange
HITECH	Health Information Technology for Economic and Clinical Health
I-Care	Central Texas HIE
IT	information technology
K	thousand
MSeHA	MidSouth e-Health Alliance
NAMCS	National Ambulatory Medical Care Survey
NwHIN	Nationwide Health Information Network
ONC	The Office of the National Coordinator for Health IT
OR	odds ratio
PICOTS	populations, interventions, comparators, outcomes, timing, types of studies, and setting
QUIS	Questionnaire for User Interface Satisfaction
RCT	randomized controlled trials
RHIO	regional health information organization
SIP	Scientific Information Packets
TEP	Technical Expert Panel
VA	Veterans Affairs
VLER	Virtual Lifetime Electronic Record