Evidence Report/Technology Assessment

Number 220

Health Information Exchange

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

The information in this report is intended to help health care decisionmakers—patients and clinicians, health system leaders, and policymakers, among others—make well informed decisions and thereby improve the quality of health care services. This report is not intended to be a substitute for the application of clinical judgment. Anyone who makes decisions concerning the provision of clinical care should consider this report in the same way as any medical reference and in conjunction with all other pertinent information, i.e., in the context of available resources and circumstances presented by individual patients.

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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 email 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.

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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.

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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 do 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 nonfinancial conflicts may be retained. The TOO and the EPC work to balance, manage, or mitigate any potential nonfinancial conflicts of interest identified.

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Health Information Exchange

Structured Abstract

Objectives. This review sought to systematically review the available literature on health information exchange (HIE), the electronic sharing of clinical 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, barriers and facilitators to actual use, implementation, and sustainability, and to present this information as a foundation on which future implementation, expansion, and research can be based.

Data sources. A research librarian designed and conducted searches of electronic databases, including MEDLINE® (1990 to February 2015), PsycINFO® (1990 to February 2015), CINAHL® (1990 through February 2015), the Cochrane Central Register of Controlled Trials (through January 2015), the Cochrane Database of Systematic Reviews (through January 2015), the Database of Abstracts of Reviews of Effects (through the first quarter of 2015), and the National Health Sciences Economic Evaluation Database (through the first quarter of 2015). The searches were supplemented by reviewing reference lists and the table of contents of journals not indexed in the databases we searched.

Review methods. Two investigators reviewed abstracts and the selected full-text articles for inclusion based on predefined criteria. Discrepancies were resolved through discussion and consensus, with a third investigator making the final decision as needed. Data were 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 136 studies overall, with 34 on effectiveness, 26 of which reported intermediate clinical, economic, or patient outcomes, and 8 that reported on clinical perceptions of HIE. We also found 58 studies on the use of HIE, 22 on usability and other facilitators and barriers to actual use of HIE, 45 on facilitators or barriers to HIE implementation, and 17 on factors related to sustainability of HIE.

No studies of HIE effectiveness reported impact on primary clinical outcomes (e.g., mortality and morbidity) or identified harms. Low-quality evidence somewhat supports the value of HIE for reducing duplicative laboratory and radiology test ordering, lowering emergency department costs, reducing hospital admissions (less so for readmissions), improving public health reporting, increasing ambulatory quality of care, and improving disability claims processing. In studies of clinician perceptions of HIE, most respondents attributed positive changes to HIE, such as improvements in coordination, communication, and knowledge about the patient. However in one study clinicians reported that the HIE did not save time and may not be worth the cost.

Studies of HIE use found that HIE adoption has increased over time, with 76 percent of U.S. hospitals exchanging information in 2014, an 85-percent increase since 2008 and a 23-percent increase since 2013. HIE systems were used by 38 percent of office-based physicians in 2012, while use remains low, less than 1 percent, 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 was not associated with effectiveness outcomes. The most commonly cited barriers to HIE use were lack of critical mass electronically exchanging data, inefficient workflow, and poorly designed interface and update features. Information was insufficient to allow us to assess usability by HIE function or architecture.

Studies provided information on both external environmental and internal organizational characteristics that affect implementation and sustainability. General characteristics of the HIE organization (e.g., strong leadership) or specific characteristics of the HIE system were the most frequently cited facilitators, while disincentives such as competition or lack of a business case for HIE were the most frequently identified barriers.

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, outcomes, 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 the HIE systems studied were 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 lack of critical mass participating in the exchange, inefficient workflow, and poorly designed interface and update features. Studies have identified numerous facilitators and barriers to implementation and sustainability, but the studies have not ranked or compared their impact. To advance our understanding of HIE, future studies need to address comprehensive questions, use more rigorous designs, use a standard for describing types of HIE, and be part of a coordinated systematic approach to studying HIE.

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Executive Summary

Background

Health information exchange (HIE) is the sharing of electronic clinical data across organizations.[1] 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 significant 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 by hospitals and health professionals. The HITECH Act designated an additional $564 million for investment by States or State-designated entities to establish HIE capability among health care providers and hospitals in their jurisdictions. Understandably, all stakeholders are interested in assuring that there is a return on this investment. These efforts have resulted in substantial growth of HIE across the United States.[2]

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 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 through the Effective Health Care Program. We used the Program's standard methods and procedures,[3] which are similar to those established by the Institute of Medicine for systematic reviews.[4] 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 research on HIE. We searched several bibliographic citation databases (e.g., MEDLINE®) with support from two specialized reference librarians, and we searched Web sites and tables of contents of publications that are not indexed in citation databases. Studies identified through these searches were reviewed for eligibility by two investigators. 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 varied widely in design and quality. We did not include studies of exchanges of data for research only, or studies about hypothetical or future HIEs. Data from included studies were abstracted from the articles, and this information was summarized in tables and narratives.

Results

Overview

The major results are summarized in Table A and described in this section.

Table A. Summary of evidence

Topic	Number and Type of Included Studies	Main Findings	Primary Limitations of the Evidence
Effectiveness	34 total: 20 retrospective cohort 3 RCT 2 cross-sectional 2 case series 8 survey (1 survey study was an RCT)	Low-quality evidence somewhat supports the value of HIE for reducing duplicative laboratory and radiology test ordering, lowering ED costs, reducing hospital admissions (less so for readmissions), improving public health reporting, increasing ambulatory quality of care, and improving disability claims processing. No studies of harm were reported.	Studies were of a small number of the functioning HIE implementations, with similarity to unstudied ones unknown, possibly limiting generalizability. Studies looked at limited outcomes, considering the intended scope of the impact of HIE.
Use	58 total: 25 survey 13 audit log 9 retrospective database 7 mixed methods 2 focus groups 1 time-motion 1 geocoding	The proportion of hospitals and ambulatory care practices that have adopted HIE is increasing. Currently, rates of HIE 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 factors affecting use	22 total: 9 multiple-site case study 11 cross-sectional 2 before-after	The most commonly cited barriers to HIE use were lack of critical mass electronically exchanging data (8 studies); inefficient workflow (10 studies); poorly designed interface and update features (7 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 description of the functionality and architecture of the systems, making comparison by type difficult.

Table A. Summary of evidence (continued)

Topic	Number and Type of Included Studies	Main Findings	Primary Limitations of the Evidence
Implementation and sustainability	52 total: 26 cross-sectional 17 multiple-site case study 2 before-after 3 retrospective cohort 2 prospective cohort 2 time series	Most facilitators of implementation cited in research were characteristics of HIE projects or the internal environment of the organizations implementing HIE, such as leadership. Most of the identified barriers to implementation were external environmental factors, such as concerns about competition. Factors related to sustainability were similar to those identified for implementation.	The research has not been designed to allow ranking or comparisons of the relative impact of different barriers and facilitators. The definition and appropriate measures of sustainability of HIE are not yet agreed upon, and the majority of projects are relatively recent.

ED = emergency department; HIE = health information exchange; RCT = randomized controlled trial

We reviewed 5,211 abstracts and 849 full-text articles. Of these, we included 136 studies that addressed one or more of our Key Questions. The data in the following sections come from a body of literature in which studies of 12 different HIE implementations are the most frequent even though they represent a small proportion of the HIEs functioning in the United States. Fewer studies were based on national surveys/datasets, and a comparatively small number of studies were conducted in other countries. Most of this literature has been published since 2006. Most studies were retrospective cohort studies (analysis of existing data comparing a certain outcome with and without HIE) or cross-sectional studies. We included several multisite case studies that consisted of qualitative analysis of data from several sources, including responses from interviews, questionnaires, or focus groups. Other less common research designs included before-and-after studies and time-series studies, which looked at what happened before and after HIE implementation. Only two randomized trials (in 3 publications) were identified. In general, the risk of bias for these studies was high, with some rated as moderate, although not all study designs were rated, and the overall strength of evidence was assessed as low or insufficient for most outcomes.

Effectiveness

We identified 34 studies that associated HIE with various outcomes, with 26 assessing the impact of HIE on resource use and 8 reporting on user perceptions of HIE impact. Studies that examined whether HIE improved resource use defined this as: (1) reduced ordering of laboratory tests, radiology exams, and costs, especially in the emergency department (ED); (2) reduced hospital admissions, hospital readmissions, and consultations; (3) successful public health use; or (4) improvement in quality of care or service delivery. The overall strength of evidence was low, as most studies were retrospective and reported on narrow questions, such as reduction in test ordering or consultations, and not larger overall clinical and financial impacts. Furthermore, the retrospective design of most of the studies raised the potential for confounding factors impacting their conclusions.

Studies of reduced laboratory tests, radiology exams, and costs showed the most consistent associated benefits. Four U.S. studies found reductions in ED orders of lab tests and radiology exams,[5-8] and three more found reductions in radiology alone.[9-11] A United States–based ambulatory study found a reduced rate of increase in laboratory testing and no impact on imaging,[12] while a Finland-based study found that orders for lab tests increased while orders for imaging decreased.[13] Two studies found that HIE reduced overall ED costs.[5,6]

The studies of admissions and readmissions had inconsistent findings, with some reporting that HIE reduced admissions[6,7,14-16] or readmissions,[17] while others reported no effect.[18-21] Similarly, the findings related to consultations or referrals were mixed, with one study reporting fewer consultations and cost savings[7] and another reporting an increase in referrals by both primary care physicians and specialists.[13] We did not pool the results using meta-analysis, as the patient populations differed across studies.

Studies of other resource-use outcomes more consistently identified benefits. Studies of quality of care found that physicians providing preventive services who used HIE performed better on quality measures.[22,23] Studies also reported that HIE could help identify frequent ED users[24] but did not lead to improvement of medication adherence.[25] One study found that HIE reduced the time needed to evaluate Social Security claims.[26] Another found a positive association between general patient satisfaction in hospitals and whether the hospital had implemented HIE.[27]

In studies that asked users of HIE to report on their perception of its impact, all found at least some benefit, although some uncovered negative aspects as well. Physicians were more satisfied with electronic than paper lab reports;[28] more physicians preferred HIE that pushed data to them than HIE that required them to pull the data with a query;[29] and physicians believed electronic reports of ED use improved followup[30,31] and that HIE improved ambulatory care practice efficiency.[32,33] However, physicians in one study responded that having HIE provide pharmacy information in the ED improved knowledge but did not reduce time spent to provide service and was not worth the cost.[34] Patients reported that they preferred having records transferred via HIE over transferring paper records themselves.[35]

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 broad based and 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 in which the results were positive, the effect sizes were not large or able to be assessed given the information provided. For example, ED savings are hard to evaluate if the overall budget for the ED is not known. (See evidence tables in Appendix F of the full report for detailed results.) Additionally, many studies employed simple study designs that impede 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 has consistently been effective in improving health outcomes.

Use of Health Information Exchange

We identified 58 studies that described either the level of use of HIE or the primary uses of HIE. Of these, 15 studies evaluated HIE use nationally in the United States and 2 studies evaluated HIE use across integrated delivery systems. About half (30 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 (10 studies), Texas (5 studies), and Tennessee (5 studies). Six studies evaluated HIE in other countries and three in multiple countries, two of which included the United States.

Nationwide surveys in the United States suggest that HIE use has risen substantially among hospitals since 2008. Use of HIE was reported by 11 percent of hospitals in 2009,[36] while more current estimates range from 30 to 58 percent.[37-39] Recent data from the Office of the National Coordinator for Health Information Technology (ONC) suggest that more than three-quarters (76%) of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with an outside provider.[2] This represents an 85-percent increase since 2008 and a 23-percent increase since 2013. Close to 7 in 10 hospitals (69%) electronically exchanged health information with ambulatory providers outside of their organization, representing a 92-percent increase since 2008 and a 21-percent increase since 2013. Results from the National Ambulatory Medical Care Survey (2013) concluded that 39 percent of office-based physicians reported having HIE capability with other providers or hospitals.[40] Limited data suggest that use of technology in general and HIE specifically is very low (> 1%) in long-term care settings.[41,42]

Between 2004 and 2009, *regional health information organization (RHIO)* was the term used to describe HIE organizations; several of the included studies used this term. All 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.[43] A study of public health departments found that 36 percent had no RHIO in their jurisdiction and 12 percent had no relationship with the RHIO in their area.[44] Of those with a RHIO in their area, 40 percent were actually exchanging information.[44] In RHIOs, the entities most commonly providing data are hospitals (83%), followed by ambulatory settings (60%); the entities most commonly receiving data are ambulatory settings (95%), followed by hospitals (83%), public health departments (50%), and payers (44%).[45]

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.[46] 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.[47]

While organizational involvement and capacity for HIE are increasing, the data about actual use of HIE when it is possible were limited and suggested that HIE is still not integrated into usual care. For example, studies from the MidSouth e-Health Alliance suggested low use of HIE overall (from 2.6% to 9.5% of visits in 2008 and 2009),[48] with higher use for ED visits (15%) and return clinic visits (19%).[49] In another example, data collected in the Central Texas HIE from 2006 to 2011, HIE use was low—used in only 2.3 percent of encounters.[50]

Usability and Other Barriers and Facilitators to Use

We reviewed 22 studies that examined either usability or other barriers and facilitators to actual HIE use. The evidence was insufficient to compare usability by type of HIE function (query-based, or pull, vs. directed, or push, exchange) or by type of architecture (centralized or not).

We found five surveys on HIE usability, and most defined usability as it relates to function and/or measured satisfaction with exchanging health information.[29,32,51-53] Perceptions of usability were related to actual use. One study reported higher scores on a measure of satisfaction with user interface related to more frequent use,[52] and another reported that users endorsing statements that the HIE was useful and easy to learn to operate had higher levels of weekly HIE use.[54] Providers who used HIE also reported increased satisfaction and improved relationships with care partners.[53,55]A related negative finding was that providers had high expectations for HIE before implementation and reported some ongoing unmet needs once HIE was operational.[53]

Barriers and facilitators to use of HIE were identified using cross-sectional and multiple-site 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: lack of critical mass electronically exchanging data, workflow, and interface. Several facilitators showed promise in promoting electronic health data exchange: obtaining more complete patient information; thoughtful implementation and workflow; and well-designed user interface and data presentation.

Lack of critical mass was 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 because of issues of incomplete patient information that related to the setting (more complete in an ED and less in a homeless center) or challenges in matching patients across systems.[46,47,56-61] Privacy, legal concerns, and requirements that patients opt in or opt out to sharing data all reduced the completeness of data, and approaches to address these factors could lead to more comprehensive data and increased use. Differences in how HIE was incorporated into workflow and daily operations also affected use.[32,47,49,51,53,54,56,60-62] Studies found that when proxy nonphysician users accessed the system and provided relevant information to the doctors, the system was used more frequently.[48,49] Studies based on observations found that different providers used the exchange differently, with nurses seeking information on hospital admissions or other care mentioned by the patients, while physicians also used the exchange to complete their understanding of the patient history and to facilitate decisionmaking.[63] The interface and features of the 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 content[61] and on interface issues, such as the need to scroll or click through multiple pages.[54,56,60] In addition, users reported that the systems slowed down as data were expanded to include more patients and information or that new information was not added to centralized systems quickly enough (so that going to records in separate systems was quicker).[54]

Implementation and Sustainability

We identified 52 studies that aimed to identify factors that affect implementation and sustainability. Forty-five studies identified facilitators to implementation (which we grouped into 8 categories) and barriers (which we grouped into7 categories). While fewer studies (17 studies) considered sustainability, we sorted the positive and negative influences on sustainability so that they overlapped with our categories of facilitators and barriers to implementation. Studies were not designed to rank factors and 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 system the organizations were planning to implement. The most frequently cited category we labeled *General Structure* of the organizations implementing HIE, and included specifics such as leadership[26,64-66] and prior experience with or readiness for information technology (IT) projects.[53,67] Another category that facilitated implementation, *HIE-Specific Structures*, included governance[26] and participatory approaches.[23,68-71] Organizations implementing HIE shifted their mission or focus (category labeled *Orientation Shift*) toward collaboration[72] and continuity of care,[73] and those that were successful were able to shift from piloting minimal HIE functions to a robust system quickly.[74] Organizations successful in implementing HIE also provided support for the implementation, such as training,[75,76] and focused on selected outcomes, such as meeting a community need.[77] *Key Functions* is our category of facilitators that included HIE designs that reflected workflow,[69] and functions that could be integrated into care processes[47,76,78,79] 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,[78,80] as well as grants from Federal and State governments that supported preliminary HIE activities and subsidized participating organizations.[67]

Barriers to implementation overlapped with facilitators but included more categories of external factors. *External Poli*cy included laws and grants that were identified as barriers when their timelines or changes in requirements imposed burdens on organizations that could mitigate the support they provided for implementation.[65,81] The most frequently cited category of barriers was *Disincentives*, including the issue of financial viability[67,75,78,82,83] and the mismatch between those who invest in HIE and those who benefit.[67,84,85] The *Technology Environment* was another category; characteristics that hindered implementation included lack of standards[44,86] and limited interoperability across organizations.[78,87,88] Three categories of barriers were related to the organization and its efforts to establish HIE: the *Lack of Necessary Components*, such as physician engagement;[72] the *Fit* between the goals and timeline of the organization and HIE projects;[89,90] and the need for resources to address complex problems with *User Interface and Functionality*.[47]

Fewer studies considered sustainability. Positive influences included factors identified as being associated with both implementation and sustainability, such as leadership by a health information organization[91] and provision of direct financial benefit to HIE participants.[84,92] The most commonly cited negative influences on sustainability were competition and the difficulty in making the business case for HIE.[93-96] Other hindrances to sustainability identified were structural factors, such as a mismatch between the geographic coverage of the HIE and the service area,[96] governance issues and lack of trust,[96,97] and lack of engagement of participating organizations and their providers.[77] One study documented that most HIE projects have overly optimistic timelines and that the lack of time and missed deadlines worked against sustainability.[74]

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, complex, systemic intervention such as HIE. While the studies of use, usability, implementation, and sustainability provide information on context and allow some insight into trends, in general they do not permit any comparative assessment or ranking of the importance of different barriers or facilitators. Additionally these studies do not provide sufficient technical detail to compare HIE systems by function or architecture.

Although it may not be the purview of research to decide if HIE should be funded as infrastructure (as with a utility) or as a part of business operations, the notion that HIE should improve efficiency and quality of care, including clinical and economic benefits, 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 that 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. We hope that this will improve as HIE implementations become more mature and more robust study designs are used. Future research should consist of prospective studies, carried out in mature HIE settings, assessing patients who are likely to benefit from HIE and comparing appropriate outcomes for the use or nonuse of HIE. The prospective collection of data from diverse settings where HIE is used, classified by a detailed taxonomy of research type, system implementation, and usage type, could allow for prospective cohort studies that could identify aspects of HIE associated with beneficial outcomes.

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 lack of critical mass exchanging data, inefficient workflow, and poorly designed interface and update features. Factors we identified as facilitating HIE implementation included general characteristics of the organization and specific characteristics of the HIE system. Barriers focused more on the external environment, and disincentives made up the largest category of barriers. Sustainability was less frequently studied; the most frequently cited negative influences were competition and the lack of a business case for 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 and around the world.[1] Health IT can support patient care delivery activities such as communications, results reporting, order entry, care planning, and documentation. Examples of health IT applications include electronic health records (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 EHR adoption 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 hospitals,[2] 78 percent of hospital-based physicians,[3] 84 percent of emergency departments, and 73 percent of hospital outpatient departments in the United States have adopted EHRs.[4] The motivation to increase the use of EHRs is grounded in evidence that health IT may improve the quality, safety, efficiency, and satisfaction with care, as has been reported in recent systematic reviews.[5-8]

A key challenge to effective use of health IT, however, is that most U.S. residents, especially those with multiple conditions, receive care across a number of settings. Among 3.7 million patients hospitalized in Massachusetts during a 5 year period, 31 percent were admitted to two or more hospitals (57% of all visits) and 1 percent were admitted to five or more hospitals (10% of all visits).[9] Similarly, an analysis of 2.8 million patients seen by an emergency department in Indiana found that 40 percent had data at multiple institutions.[10] These data silos present 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, attention is now focused on health information exchange (HIE), 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 is insufficient to realize the full promise of health IT, allocating $563 million for States or State-designated entities to establish HIE capability among health care providers and hospitals in their jurisdictions.[13] In the meantime, a growing number of private organizations have undertaken HIE.[14] Ideally, HIE across health care organizations should facilitate care coordination and transitions between settings, improve patient safety, and reduce duplicate testing.

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

- Directed exchange: sending and receiving 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.

ONC also uses the words "push" to describe directed exchange and "pull" to describe query-based exchange.[15]

In general, HIE is defined as the electronic exchange of patient data across health care organizations. This excludes exchange of information that is predominantly paper-based as well as queries of remotely accessed systems (e.g., a clinician in one health care system seeking information residing in a system of another health care organization accessed over the Internet). Many also advocate that HIE be used as a verb or activity-based noun, and not as an entity or organization, even though many HIE implementations and/or the organizations implementing them call themselves "HIEs."[16,17]

An early example of HIE was the work of Dr. Clement McDonald, who pioneered HIE in Indiana starting in the 1990s.[18] This led to the formation of the Indiana Health Information Exchange, one of the largest and most successful HIE efforts in the United States.[19] Other early efforts to implement HIE, including some high-profile efforts, were less successful.[20] Although the rationale for HIE has been viewed as critical,[21] the path to achieve it has in some respects been more difficult than EHR adoption,[22,23] in no small part due to the lack of sustainable business models.[24,25] Nonetheless, HIE adoption has grown as a result of the HITECH Act.[26]

Another barrier to HIE has been the development and adoption of health IT standards to ensure interoperability among systems. This has driven ONC, the lead U.S. government agency for health IT, to prioritize interoperability in its most recent strategic plan for health IT.[27] ONC has also launched a process to establish an interoperability roadmap for guiding implementation of standards and interoperability, which also has the potential to facilitate adoption and improvement of HIE.[28] An additional barrier to HIE described by ONC is "information blocking," which is the unintentional or deliberate prevention of information exchange between health IT systems.[29]

Evaluating the effectiveness of HIE (and health IT generally) has been challenging.[30] HIE is a technology that is intermediate to improving care delivery, allowing clinicians and others improved access to patient data to inform decisions and facilitate appropriate use of testing and treatment. HIE is not specific to any health issue or diagnosis. HIE implementations have often been supported by one-time start-up funding, without long-term support to sustain the programs long enough for evaluation.

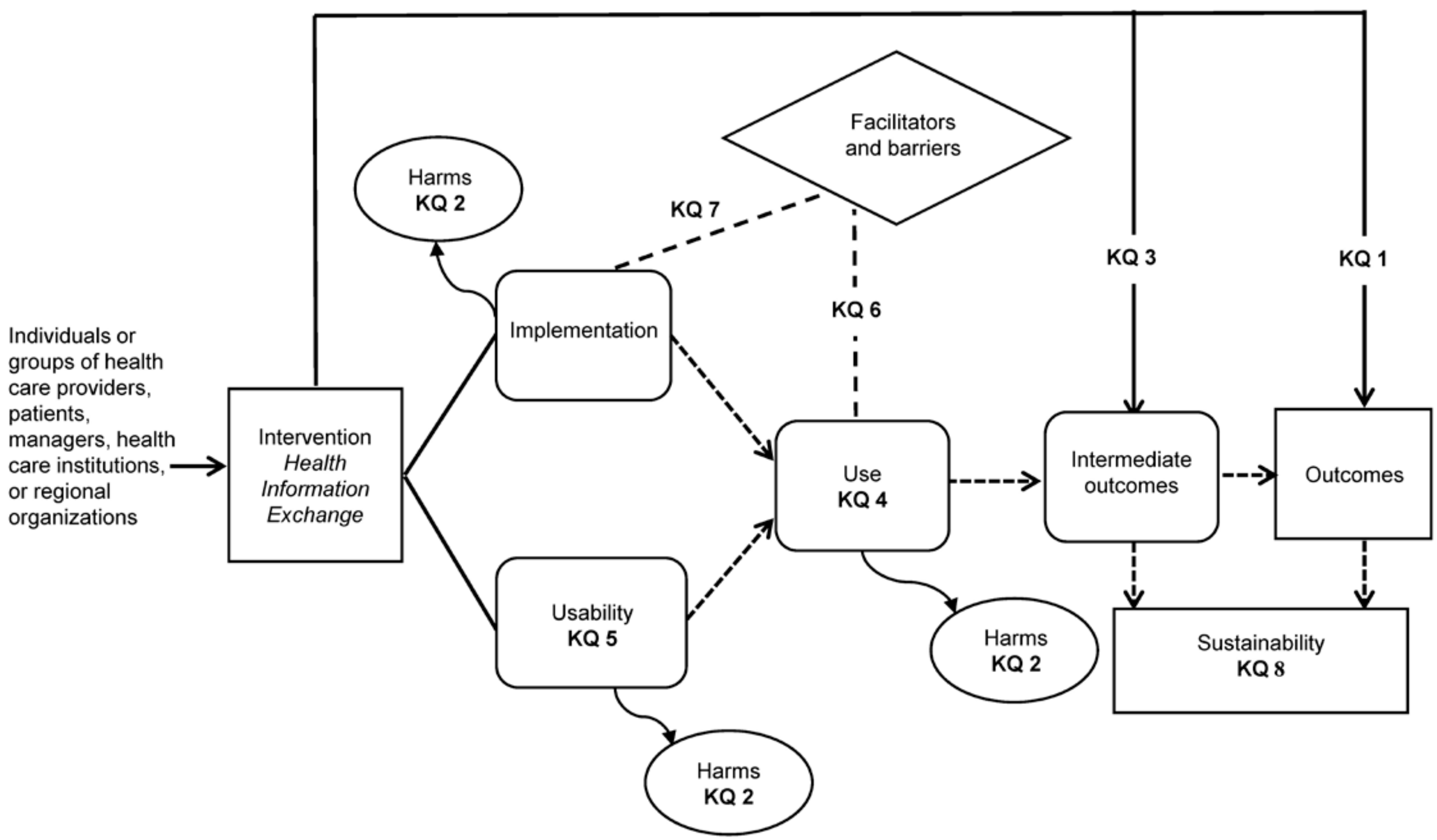
The promise for HIE to improve health care delivery is substantial, but adoption in its various forms has been complex and costly. It is therefore critical to be able to determine if HIE does improve health or intermediate outcomes as well as to systematically assess comparative approaches, barriers, 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 demonstrates an evidence base that is scattered across disciplines and in various formats. There are three previously published systematic reviews that focus exclusively on HIE.[31-33] One of these reviews is almost a half-decade old,[31] another focused only on U.S.-based and clinical-only (i.e., not public health) activities,[32] and a third assessed only care outcomes and not larger issues of facilitators, barriers, and sustainability.[33]

In requesting this review, AHRQ's goal is a report focused on systematically identifying and synthesizing evidence on the extent to which HIE can effectively improve a variety of outcomes, and to determine if it is possible to say how the impact varies by different approaches to HIE. This is due in part to AHRQ having funded a large portfolio of research in health IT and HIE,[34] and having published an extensive guide to evaluating HIE projects.[35] This report also aims 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



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 are 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."[36]

Topic Development and Refinement

The initial draft Key Questions were first provided by AHRQ, who requested this 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 revised and developed by the review team with input from a group of stakeholders (Key Informants) convened for this review to provide diverse perspectives as well as content and methodological expertise. The Key Informants consisted of experts in health IT, applied informatics, clinical care, health policy and patient advocacy. 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.

The project team, with input from a Technical Expert Panel (TEP) convened for this review, further developed the approach to this review. The TEP added expertise in informatics research and systematic reviews to the perspectives that were represented by the Key Informants. The Key Informants and TEP members are listed in the front matter. 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 July 21, 2014 on the AHRQ Web site at: http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/?productid=1943&pageaction=displayproduct. The protocol was subsequently revised to document a change in the numbering of the Key Questions and reposted. The original protocol was also registered in the PROSPERO international database of prospectively registered systematic reviews.[37]

Literature Search Strategy

A research librarian conducted searches in Ovid MEDLINE (1990 to February 2015), PsycINFO (1990 to February 2015), CINAHL (1990 through February 2015), the Cochrane Central Register of Controlled Trials (through January 2015), Cochrane Database of Systematic Reviews (through January 2015), the Database of Abstracts of Reviews of Effects, and the National Health Sciences Economic Evaluation Database (through the first quarter of 2015). See Appendix A for the detailed search strategies. Searches were peer reviewed by a second librarian with systematic review experience 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. Our search strategy was based on a broad terms and we evaluated this approach in several ways including determining if it successfully identified examples of several types of studies. During our literature scan we screened a sample of citations from two additional databases: Business Premier and the Institute of Electrical and Electronics Engineers (IEEE) *Xplore* Digital Library; neither screen resulted in identification of relevant articles and the databases were not searched further. 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 were requested from organizations likely to have data on research or evaluations of health information exchange (HIE) that have not been published or indexed in citation databases. These organizations had the opportunity to submit data using the portal for submitting Scientific Information Packets on the Effective Health Care Program Web site. One submission was received from the California Health Care 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) defined in the protocol (Appendix B). Papers were selected for review if they reported data about HIE (as defined below), had data relevant to a Key Question, and met the other pre-specified inclusion criteria. Studies of nonhuman subjects and studies with no original data were excluded. Abstracts were independently reviewed by two investigators for inclusion. 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. Sample sets of abstracts and full text articles were reviewed by the entire team at key points in the review process to establish norms. 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 during team meetings with investigators.

Populations

Study population included any individual or group of health care providers, patients, managers, health care institutions, or regional organizations.

Intervention and Comparators

We defined HIE as the electronic sharing of clinical information among users such as clinicians, 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. We did not include in this definition of HIE the exchange of information within a single organization or entity (e.g., exchange within a network such as Kaiser Permanente or the Veteran's Administration or exchange across roles such as patient and clinician communications within a provider organization).

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 was 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 included 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 may result from too much information or insufficient information, or include negative impacts on attitudes (e.g., patient privacy concerns or clinician liability concerns).

Key Question 3: Intermediate outcomes included clinician and patient experiences and perceptions; changes in individual behavior or care delivery processes; and changes in the availability, completeness or accuracy of information.

Key Question 4: Level of use was a measure of the usage of HIE use by individuals, health care institutions, or regional organizations.

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

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

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

Key Question 8: Sustainability was long-term maintenance, development, 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

Settings included any aspect of the location or venue in which health information is exchanged for the purpose of improving health or health care that is hypothesized to impact effectiveness, use, usability, or sustainability. This included the type(s) of clinical environments (e.g., ambulatory care, hospital, nursing home), payment/reimbursement model(s) (e.g., fee-for-service, managed care, risk/value-based model such as an accountable care organization), and legislative requirements (e.g., participation in HIE required to participate in Medicaid). Also included were studies in public health organizations and settings; those using HIE data for clinical research were excluded.

Study Design

Our approach to decisions about what designs and units of analysis to include varied across the Key Questions, reflecting the fact that different types of research was needed to answer different types of questions.

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, observational studies (defined as cohort studies comparing at least two HIE systems, case-control studies, and time-series studies) were explored.

For questions on use, usability, implementation, and sustainability, observational studies and qualitative research were included. We also included detailed case studies of multiple HIE organizations or sites. For studies of use and usability we included examinations both on the individual level and organizational level, while implementation and sustainability were defined as organizational level activities.

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 this 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.[36,38]

We excluded studies that modeled the potential impact of HIE or that presented, discussed, or evaluated hypothetical situations about HIE not yet implemented. Also excluded were descriptive narratives or "lessons learned" essays that were not based on collecting clinical, survey, or interview data from identified 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.

See Appendix E for the study design terminology used in this review.

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 implementation 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 vs. 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), and relevant outcomes. Abstracted information is included in Appendix F and is also available in the Systematic Review Data Repository.

Assessment of Methodological Risk of Bias of Individual Studies

Assessment of risk of bias of trials and observational studies was based on recommendations in the AHRQ Methods Guide for Effectiveness and Comparative Effectiveness Reviews.[36] Two investigators independently assessed risk of bias for all effectiveness studies. Differences were resolved by discussion and consensus and reviewed by the team of investigators. 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 G.

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 informed our descriptions of the studies and assessment of both the strength of evidence and the specific needs for future research. Appendix G includes a list of the information we recorded. Risk of bias was not assessed for 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 with summary tables to highlight the main findings. For each study, 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 found heterogeneity in the interventions and outcomes measured, including how similar outcomes were measured and reported, such that we did not conduct meta-analyses. We combined studies in the synthesis of the results based on the similarity of the type of HIE, the implementation of the HIE, outcomes measured, and results reported. Where studies were not similar in these areas we provided the results of the invidvidual studies without combining them.

The evidence for Key Questions 1, 2, and 3 were summarized and presented together as there were few studies that reported on primary clinical outcomes and no studies that explicitly analyzed harms. Many studies that reported 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 implementation was analyzed. For Key Question 4 there were two categories of studies: large, mostly national surveys that examined HIE use on a macro level (e.g., which organizations did or did not use HIE); and studies that examined how HIE was used within organizations. We presented 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 presented the results for Key Questions 7 and 8 together 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 addressed implementation and sustainability, or addressed 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 categories of facilitators and barriers. We grouped the factors identified in the literature into categories in order to provide a summary.

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 Questions 1, 2, and 3 using the four categories recommended in the AHRQ Methods Guide.[36]

- 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 H.

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.

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.[36] 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 a 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 a 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 were performed.

Peer Review and Public Commentary

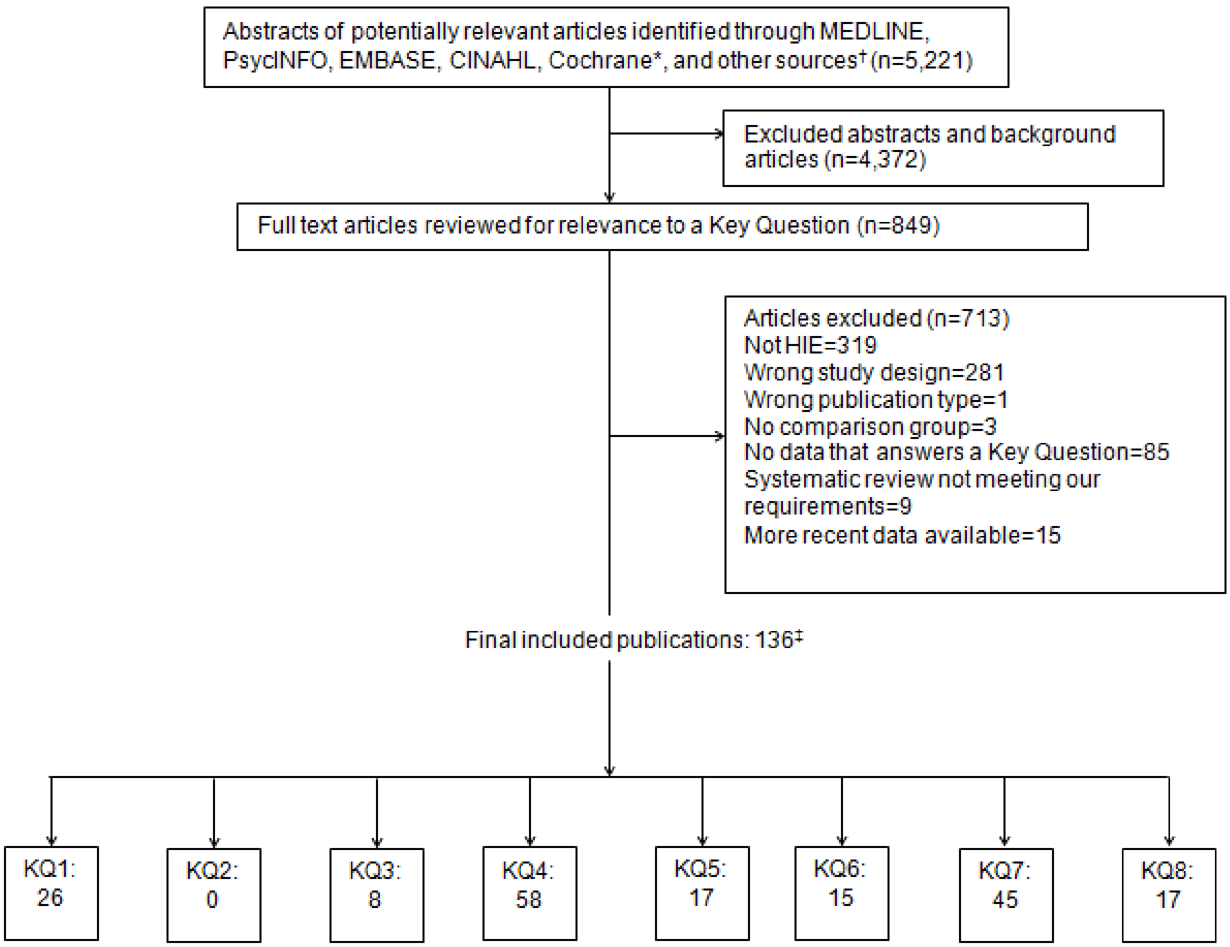
Experts in HIE, individuals representing important stakeholder groups, and Technical Expert Panel members were invited to provide external peer review of this systematic review. The AHRQ Task Order Officer and a designated Evidence-based Practice Center Associate Editor also provided comments and editorial review. To obtain public comment, the draft report was posted on the AHRQ Web site for 4 weeks from March 12 to April 8, 2015. 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 5,211 potentially relevant citations. After dual review of abstracts and titles, 849 articles were selected for full-text review. After dual review of full text articles, 136 studies were included. Data extraction and risk of bias assessment tables for included studies are available in Appendixes F and I.

Figure 2. Literature flow diagram



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, and National Health Sciences Economic Evaluation Database.
†Identified from reference lists, hand searching, suggested by experts, and other sources.
‡Publications may address more than one Key Question, studies may have multiple publications.

Description of Included Studies

Of the 136 studies included in this review, two randomized controlled trials (RCTs) described in three papers and 32 observational and survey studies addressed Key Questions 1, 2, and 3, pertaining to the effectiveness of improving clinical, economic, population, and intermediate outcomes. Most were conducted in the United States, although eight were from Europe, Canada, Israel, and South Korea. Most studies reported clinical or public health process, economic, or population outcomes, while no studies reported harms of health information exchange (HIE). The majority were assessed to be of low risk of bias but also contained low-quality, mostly retrospective evidence. We identified 58 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. Twenty-two 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. A total of 52 studies addressed Key Questions 7 and 8, related to HIE implementation and sustainability. These studies used varying types of qualitative methods; for those that could be assessed for risk of bias, most were found to have a high risk of bias.

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 studied 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 reported 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 was low.
- Most studies also reported positive results, raising concerns about publication bias.

Detailed Synthesis

We identified 34 studies that assessed some sort of outcome from HIE use (Table 1). Mapping to our original Key Questions, a total of 26 studies were deemed to report clinical (intermediate), economic, or population outcomes (Key Question 1), while eight were found to report on perceptions of outcomes (Key Question 3). However, no studies evaluated primary clinical outcomes from HIE (e.g., mortality and morbidity - Key Question 1), and none explicitly assessed harms (Key Question 2). Additionally, some studies reported outcomes for more than one of the outcomes in the 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.[39-56] The next most common design was survey, which was usually focused on perception of outcomes.[57-64] Two studies were RCTs, one of a particular directed information exchange (2 published papers, 1 on clinical outcomes[65] and the other on perceptions[66]) and the other of a clinical decision support intervention using data from an HIE implementation.[67] Two studies used cross-sectional analyses of large databases to compare those having access to HIE with those without access.[68,69] Two other studies used a case series methodology, one of which involved asking clinicians if HIE access avoided undesirable resource use, and then calculating the costs saved[70] and the other that retrospectively analyzed data to determine duplicative testing averted.[71]

The identified studies were performed mostly in the United States, but we identified eight studies from five other countries (Austria,[62] Canada,[65,66] Finland,[46,61] Israel,[41,72] and South Korea[63]). Of the 26 U.S. studies, three assessed multiple HIE implementations in two states (1 study)[69] and the entire country (2 studies).[64,68] The remaining 23 studies were conducted (1 study per State unless otherwise noted) in Colorado,[50] Indiana (3 studies),[42,49,59] Louisiana,[47] Massachusetts,[60] Minnesota[71], North Carolina,[67] New York (6 studies),[45,51,55-58] Oklahoma,[48] South Carolina,[70] Tennessee (3 studies),[39,40,44] Texas,[54] Virginia,[43] and Wisconsin (2 studies).[52,53]

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 HIE implementations in 2013[73] and 106 in 2014.[74] In other words, while a substantial number of HIE implementations exist in the United States, only a small number have been subject to evaluation. This low number of studies relative to HIE efforts also makes it difficult to generalize factors about aspects of them, such as location, HIE type, and setting, with results of research.

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

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								
Mäenpää et al., 2011[46]	Tampere, Finland	Outpatient	Query	Retrospective cohort	Low	Negative	Lab test ordering	Increased lab testing
Ross et al., 2013[50]	Mesa County, Colorado	Outpatient	Query	Retrospective cohort	Low	Beneficial	Rate of increase in lab testing	Reduced rate of increase in lab testing
Carr et al., 2014[70]	Charleston, South Carolina	ED	Query	Case series	Moderate	Beneficial	Lab testing	Reduced lab testing
Frisse et al., 2012[44]	Memphis, Tennessee	ED	Query	Retrospective cohort	Moderate	Beneficial	Lab testing	Reduced lab testing
Tzeel et al., 2011[52]	Milwaukee, Wisconsin	ED	Query	Retrospective cohort	Low	Beneficial	ED visit costs	Decreased with HIE use; driven by reduced testing
Winden, et al., 2014[71]	Minnesota	ED	Query	Case series	Moderate	Beneficial	Lab testing	Reduction of duplicate lab testing
Radiology Testing								
Bailey et al., 2013[39]	Memphis, Tennessee	ED	Query	Retrospective cohort	Low	Beneficial	Use of neuroimaging	Reduced imaging
Bailey, et al., 2013[40]	Memphis, Tennessee	ED	Query	Retrospective cohort	Low	Beneficial	Use of back imaging	Reduced imaging
Carr et al., 2014[70]	Charleston, South Carolina	ED	Query	Case series	Moderate	Beneficial	Use of radiology testing	Reduced imaging
Frisse et al., 2012[44]	Memphis, Tennessee	ED	Query	Retrospective cohort	Moderate	Beneficial	Use of radiology testing	Reduced imaging
Lammers, Adler-Milstein, and Kocher, 2014[69]	California and Florida	ED	Varied	Cross-sectional	Low	Beneficial	Reimaging in ED	Reduced imaging among those who implemented HIE

Table 1. Studies of HIE included for assessing outcomes (continued)

Study	Location	Setting	HIE Type	Study Type	Risk of Bias	Direction of Result(s)	Outcome(s) Assessed	Results
Radiology Testing (continued)								
Mäenpää et al., 2011[46]	Tampere, Finland	Outpatient	Query	Retrospective cohort	Low	Beneficial	Use of radiology testing	Reduced imaging
Ross et al., 2013[50]	Mesa County, Colorado	Outpatient	Query	Retrospective cohort	Low	None	Use of radiology testing	No impact on imaging
Tzeel et al., 2011[52]	Milwaukee, Wisconsin	ED	Query	Retrospective cohort	Low	Beneficial	ED visit costs	Decreased with HIE use; driven by reduced testing
Winden, et al., 2014[71]	Minnesota	ED	Query	Case series	Moderate	Beneficial	Use of radiology testing	Reduction of duplicate imaging
Hospital Admissions								
Ben-Assuli, Shabtai, and Leshno, 2013[41]	Israel	HMO	Query	Retrospective cohort	Low	Beneficial	Hospital admissions	Decreased with HIE use
Ben-Assuli, Shabtai and Leshno, 2015[72]	Israel	HMO	Query	Retrospective cohort	Low	Beneficial	Hospital admissions	Decreased with HIE use
Frisse et al., 2012[44]	Memphis, Tennessee	ED	Query	Retrospective cohort	Low	Beneficial	Hospital admissions	Decreased with HIE use
Carr et al., 2014[70]	Charleston South Carolina	ED	Query	Case series	Moderate	Beneficial	Hospital admissions	Decreased with HIE use
Tzeel et al., 2012[53]	Milwaukee, Wisconsin	ED	Query	Retrospective cohort	Low	Mixed	Hospital admissions Length of Stay	Increased admissions but decreased LOS
Vest, 2009[54]	Austin, Texas	ED	Query	Retrospective cohort	Low	Beneficial	Hospital admissions for ambulatory-sensitive diagnoses in indigent patients	Increased with use of HIE
Vest et al., 2014 [56]	Rochester, New York	ED	Query	Retrospective cohort	Low	Beneficial	Hospital admissions	Reduced with HIE

Table 1. Studies of HIE included for assessing outcomes (continued)

Study	Location	Setting	HIE Type	Study Type	Risk of Bias	Direction of Result(s)	Outcome(s) Assessed	Results
Hospital/ED Readmissions								
Lang et al., 2006[65]	Montreal, Canada	ED	Directed	RCT	Moderate	None	ED return visits	No difference
Vest et al., 2014 [55]	Rochester, New York	ED	Query	Retrospective cohort	Low	Beneficial	Hospital readmissions	Decreased with HIE use
Jones, Friedberg and Schneider, 2011[68]	U.S.	All	Varied	Cross-sectional	Low	None	Hospital readmissions	No difference
Referrals and/or Consultations								
Carr et al., 2014[70]	Charleston, South Carolina	ED	Query	Case series	Moderate	Beneficial	Consultation	Reduced with HIE use
Mäenpää et al., 2011[46]	Tampere, Finland	Outpatient	Query	Retrospective cohort	Low	Mixed	Referral ordering	Increased referrals with HIE
Emergency Department Costs								
Frisse et al., 2012[44]	Memphis, Tennessee	ED	Query	Retrospective cohort	Low	Beneficial	Overall cost	Decreased with HIE use
Tzeel et al., 2011[52]	Milwaukee, Wisconsin	ED	Query	Retrospective cohort	Low	Beneficial	ED visit costs	Decreased with HIE use; driven by reduced lab testing
Public Health Reporting								
Magnus et al., 2012[47]	Louisiana	Public health	Directed	Retrospective cohort	Low	Beneficial	Followup care for HIV patients	Improved with HIE
Dixon, McGowan and Grannis, 2011[42]	Indiana	Public health	Directed	Retrospective cohort	Low	None	Completeness of public health reporting	Incomplete due to poor quality of clinical data
Overhage et al., 2008[49]	Indiana	Public health	Directed	Retrospective cohort	Low	Beneficial	Identification and completeness of notifiable disease reporting	Increased notifiable diseases found and completeness of data for diseases found

Table 1. Studies of HIE included for assessing outcomes (continued)

Study	Location	Setting	HIE Type	Study Type	Risk of Bias	Direction of Result(s)	Outcome(s) Assessed	Results
Quality of Ambulatory Care								
Kern et al., 2012[45]	Hudson Valley, New York	Outpatient	Query	Retrospective cohort	Low	Beneficial	Clinical quality measures	Increased with HIE
Nagykaldi et al., 2014[48]	Norman and Oklahoma City, Oklahoma	Outpatient	Query	Retrospective cohort	Moderate	Beneficial	Clinical quality measures	Increased with HIE
Willis et al., 2013[67]	North Carolina	Outpatient	Query	RCT	Moderate	Beneficial	Documentation and medication reconciliation	Increased with HIE
Other Aspects of HIE								
Feldman and Horan, 2011[43]	Virginia	Government	Directed	Retrospective cohort	Moderate	Beneficial	Case processing time for SSD determination	Decrease in mean case processing time
Shapiro et al., 2013[51]	New York	ED	Query	Retrospective cohort	Moderate	Beneficial	Identification of frequent ED users	Increased with HIE
Vest and Miller, 2011[64]	U.S.	Hospital	Varied	Cross-sectional	Low	Beneficial	Patient satisfaction with hospital care	Higher in implemented than adopted hospitals

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 3 publications) and one other study with a prospective design, most studies used retrospective designs, usually with an approach examining the association of HIE use 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 neither study showed benefit of HIE. The other prospective study was limited by methodology of physicians 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, questions of external validity remain, especially since the intervention (HIE) was only one of many potential influences on clinical outcome (i.e., many more factors go into clinical outcomes than the decision to consult an HIE system on a patient). As a result, most studies with appropriate retrospective methods are listed as having low or moderate risk of bias due to their proper internal validity but there are still significant concerns about external validity.

Improving Resource Use

Laboratory Testing

Six studies addressed laboratory testing, with five finding a benefit of HIE in reducing overall tests, although estimates of impact on cost were mixed.[44,46,50,52,70,71] Four of these studies took place in the ED setting, all showing some aspect of reduced testing and cost savings. Two studies found overall reduced laboratory testing, 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)[44] 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.[52] A third study logged physician self-reports of laboratory testing averted with use of HIE in the ED, with savings over 3 months of $462 calculated from tests reportedly not ordered.[70] A fourth study found 96 instances of duplicate lab testing averted in 1,488 patient encounters that were retrospectively analyzed.[71]Two studies were conducted in ambulatory settings, against a backdrop of increased overall laboratory testing. One U.S. study found that after HIE implementation, there was a reduction in the rising rate of testing, without overall cost savings.[50] In contrast, a study in Finland found increased laboratory testing during the period of HIE implementation (19.0% for primary care physicians and 7.0% for specialist physicians per total patient appointments).[46] As with all retrospective studies, the four studies of laboratory testing could have been complicated by confounders, while the prospective study did not validate physician self-reporting of tests avoided or measure overall costs of care for the ED encounter or subsequent utilization.

Radiology Testing

Nine studies assessed radiology testing, with all but one reporting an association of reduced testing with HIE.[39,40,44,46,50,52,69-71] Six of these studies also examined laboratory testing and are described previously,[44,46,50,52,71,75] and three additional ED studies assessed only imaging.[39,40,69]

The ED studies showed a variety of findings. One study found that for all radiologic imaging, there was reduction of head computed tomography (CT) imaging, (OR of 0.913, 95% CI, 0.842 to 0.991) as well as body CT imaging (OR 0.886, 95% CI, 0.828 to 0.948) but no significant changes in echocardiogram, chest x-ray, or ankle x-ray testing across 12 EDs.[44] Another study 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.[52] Two additional studies assessed neuroimaging for headache[39] and repeat imaging for back pain in EDs.[40] 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 was no significant change 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. A prospective case series study reported $161K in savings over 3 months through averted radiologic testing in EDs,[70] while a retrospective case series found 453 duplicate radiology testing in 1,488 patient encounters retrospectively analyzed.[71]

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.[69]

In ambulatory settings, one U.S. study showed no statistically significant reduction in the rate of radiologic testing.[50] However, a Finland-based study showed a reduction in radiologic testing (16.4% reduction for primary care physicians and 11.0% reduction for specialist physicians).[46]

Hospital Admissions

Eight studies assessed the role of HIE in reducing hospital admissions, with inconsistent findings.[41,44,53,54,56,65,70,72] Two studies (described above) found a reduction in hospital admissions and lower costs using methods previously described. The bulk of the $1.07 million annual savings due to HIE found in one study resulted from reduced admissions.[44] Another study also reported $118K in savings from averted admissions over a 3-month period.[70] Two studies in an Israeli health maintenance organization found that viewing the medical history via an electronic health record (EHR) decreased possibly redundant admissions, with even greater reductions when information was accessed using HIE.[41,72] A study in New York found that viewing information reduced odds of admission (OR 0.70; 95% CI, 0.52 to 0.95).[56]

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.[65] Other studies found that HIE was associated with increased admissions for ambulatory-sensitive diagnoses[54] 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 over 16 months.[53]

Two studies assessed HIE in reducing hospital readmissions. One study found that assessing information in an HIE implementation was associated with reduced odds of hospital readmission (OR 0.43; 95% CI, 0.27 to 0.70)[55] while another found that U.S. hospitals participating in HIE in 2007 did not have lower readmission rates for acute myocardial infarction, pneumonia, or heart failure.[68]

Referrals and Consultations

Two studies, described previously, assessed HIE for reducing referrals and/or consultations. The prospective ED case series reported reduced consultations, leading to savings of $3,990 over 3 months.[70] The Finland-based ambulatory study, however, found that HIE was associated with increased referrals by primary care physicians (43.6%) and specialists (12.8%).[46]

ED 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 system 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.[44] 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.[52] Neither study reported overall ED expenditures, making it unknown what proportion of overall ED spending was impacted by HIE.

Public Heath Reporting

Three studies assessed HIE in public health settings, all of which were conducted in the United States.[42,47,49] Two examined the completeness of notifiable disease reporting data. 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.[49] 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.[42] 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.[47]

Quality of Care

Three studies looked at the value of HIE in improving quality of care in ambulatory settings.[45,48,67] One study assessed a benchmark group of clinical quality measures believed to be amenable to HIE usage among users and nonusers 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 ($p<0.001$).[45] 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 by patients in taking medications prescribed based on evidence-based guidelines.[67] 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).[48] The study also found that medication reconciliation completion improved from 35.3 percent to 44.9 percent (p<0.001).

Other Aspects of HIE

Three studies assessed other aspects of HIE. One study found a 30 percent reduction in evaluation time for Social Security Disability claims.[43] Another found that HIE data led to a 20.3 percent increase in identifying frequent ED users compared with site-specific data.[51] An additional study focused on hospital-based HIE, finding that communication and satisfaction (based on the Hospital Consumer Assessment of Healthcare Providers and Systems survey) were higher in hospitals that implemented HIE compared with those that proposed to implement HIE.[64]

Although the risk of bias in most studies was low, the resulting evidence from them was mostly of low quality. This low strength evidence mostly favored the value of HIE in reducing resource use and costs, especially in the ED. However, these studies used 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 number of studies evaluated clinician or patient perceptions of HIE (Table 2).[57-64,66] 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,[65] with family physicians reporting improved patient management and followup in ED settings. [66] Another study also found that primary care physicians reported enhanced awareness and improved communication and followup with primary care physicians after ED admission/discharge.[57] An additional study found that providing pharmacy information to physicians in the ED improved knowledge and gaps but was not felt to reduce time or be worth the cost.[60]

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 decisions[61] and improved care and decreased work for filing and archiving discharge reports that were sent.[62]

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.[59] Another queried physicians on push versus pull HIE, with respondents reporting satisfaction with both, although more so with push over pull.[58] An additional study assessed patient satisfaction when records were transferred via HIE, finding it to be improved over patients delivering paper records themselves.[63]

Clinician perceptions of the value of HIE, where studied, were generally positive. How such perceptions translate into improved care is unknown. This body of evidence was of low strength.

Table 2. Patient and clinician perceptions of HIE

Study	Location	Setting	HIE Type	Study Type, Data Source	Risk of Bias	Direction of Result(s)	Perception(s) Assessed	Results
Afilalo, et al., 2007[66]	Montreal, Canada	ED	Directed	RCT, survey	Moderate	Beneficial	Outcomes improved, better patient management	Improved with HIE
Altman et al., 2012 [57]	New York	ED	Directed	Cross-sectional survey	Moderate	Beneficial	PCP notification of ED admission/discharge	Enhanced awareness and improved communication and followup
Campion et al., 2012[58]	Rochester and Buffalo, New York	Outpatient	Both	Cross-sectional, survey	Moderate	Beneficial	Physician satisfaction of push vs. pull	Satisfied with both, more with push than pull
Chang et al., 2010[59]	Indiana	Outpatient	Query	Cross-sectional, survey	Moderate	Beneficial	Physician satisfaction with electronic lab reports	Favorable, including over traditional reports
Kaushal et al., 2010[60]	Massachusetts	ED	Directed	Cross-sectional, survey	High	Mixed	Impact of providing pharmacy information	Improved knowledge and gaps but not felt to reduce time or be worth the cost
Maass et al., 2008[61]	Finland	Outpatient	Query	Cross-sectional, survey	High	Beneficial	Improvements in care	When HIE used, faster results acquisition and treatment decision
Machan, Ammenwerth, and Schabetsberger, 2006[62]	Tyrol, Austria	Outpatient	Directed	Cross-sectional, survey	Low	Beneficial	Physician satisfaction with discharge reports sent	Improved care and decreased work for filing and archiving
Park et al., 2013[63]	South Korea	Outpatient	Directed	Cross-sectional, survey	Low	Beneficial	Patient perceptions of data transferred	Increased satisfaction for patients whose records transferred via HIE

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 was not an indicator of the overall direction of the evidence, we did note that for each "negative" study, there is at least one "positive one.
For "Type of HIE," there was 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.[65,67] A perceptions study of one of the RCTs found perceptions of improved patient outcomes and their management.[66] These are in contrast 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 ambulatory and ED have enough studies to evaluate patterns, with outpatient settings less likely to find beneficial results compared with studies in ED settings, but again based on indirect comparisons only.
The sparseness of studies across geographic settings does not allow for identification of patterns, although across most studies in the United States, the findings were positive.

Table 3. Factors that may affect outcomes

Factor	Studies of Outcomes	Studies of Perceptions	Studies Reported as Beneficial	Studies Reported as No Benefit	Total
Study Type					
Retrospective cohort	20		19	1	20
Randomized controlled trial	2	1	1	2	3
Cross-sectional	2		1	1	2
Case series	2		2		2
Survey*		8	8		8
Setting					
All	1			1	1
Emergency department	13	3	13	3	16
Government	1		1		1
HMO	2		2		2
Hospital	1			1	1
Outpatient	5	5	9	1	10
Public health	3		3		3
Location					
U.S. multistate	3		2	1	3
Colorado	1		1		1
Indiana	2	1	3		3
Louisiana	1		1		1

Table 3. Factors that may affect outcomes (continued)

Factor	Studies of Outcomes	Studies of Perceptions	Studies Reported as Beneficial	Studies Reported as No Benefit	Total
Massachusetts	1		1		1
Minnesota	1		1		1
North Carolina	1			1	1
New York	4	2	6		6
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
Canada	1	1	1	1	2
Finland	1	1	1	1	2
Israel	2		2		2
South Korea		1	1		1
HIE Type					
Directed	5	5	8	2	10
Query	18	2	19	1	20
Multiple	3	1	3	1	4

HIE = health information exchange; HMO = health maintenance organization; vs. = versus
*1 survey study was also an RCT.

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

Key Points

- More than three-quarters (76%) of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with any outside providers in 2014. This represented an 85 percent increase since 2008 and a 23 percent increase since 2013. Close to seven in 10 hospitals (69%) electronically exchanged health information with ambulatory providers outside of their organization, representing a 92 percent increase since 2008 and a 21 percent increase since 2013.
- 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 health system (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. Less than four in ten residential care facilities that use EHRs also exchange health information.
- 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.
- HIE use was in its infancy in the 2000s but has been steadily increasing since then.
  - A recently released 2015 report from the ONC suggests that the United States is making great progress in exchanging health information.
  - 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.

Detailed Synthesis

We identified 58 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 (25 studies),[25,26,73,74,76-96] analyses of HIE audit-logs (13 studies),[40,45,54,97-106] retrospective database analyses (9 studies),[107-115] and mixed methods (7 studies).[116-122] Two studies used focus group methods,[123,124] one study used time-motion methods,[61] and another used geo-coding.[125]

Over one-half of the studies (30 of 58) analyzed HIE implementations over a regional or statewide area,[45,54,76,77,83-86,88,90,92,96-106,112,118-120,123-126] while an additional 15 evaluated HIE use nationally.[25,26,78-81,87,91,93,107-111,113] Of those that evaluated use regionally or over a statewide area, 10 studies evaluated HIE implementations in the State of New York,[45,76,77,96-98,102,106,112,125] five in Texas,[54,101,103-105] five in Tennessee,[40,86,99,118,119] two in Indiana,[88,92] and two in Minnesota.[85,90] Five studies evaluated HIE in a single State (Massachusetts,[123] North Carolina,[100] Wisconsin,[84] Northeastern Ohio,[120] and Louisiana[124]).

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 non-Federal care organizations,[116] and the other between the VA and Kaiser Permanente.[82] Seven studies evaluated HIE use outside of the United States[61,89,94,114,115,121,122] and two in multiple countries including the United States.[95,117]

The majority of studies evaluated HIE use across inpatient and ambulatory care settings. Seven studies were limited to evaluations of HIE use in hospitals,[76,88,96,107,108,111,117] three of these used data from the American Hospital Association (AHA).[107,108,111] Four studies evaluated HIE use that involved exchange of data with nursing homes or residential care facilities; two using data from the National Nursing Home Survey and the National Survey of Residential Care Facilities,[93,113] the other two using data from New York State.[77,112] Three studies focused on evaluating HIE use in the ED; all of these exchanged data regionally.[40,99,100] Two studies focused on evaluating HIE use in office settings using data from the National Ambulatory Medical Care Survey,[91,110] three others used within State data, one from Indiana[92] and two from Minnesota.[85,90]

The majority of studies assessed overall use of the HIE, while two assessed the use of HIE for repeated imaging in the ED,[40,102] and two evaluated HIE for prevention or tracking of infections.[83,88]

Twenty-seven studies included data collected in 2010 or more recently;[25,26,73,74,77,83,88,90-98,102,106,108-113,120,124,125] the majority of studies used data collected in 2009 or earlier. Fifteen studies used a query-based HIE;[40,54,86,97-99,101-105,118-120,125] the other studies either did not specify, or multiple HIE implementations were included.

Twenty-nine of the studies were rated as being at low risk of bias;[25,26,40,54,76-81,83,86,88,91,93,94,100,101,103-105,107-111,113,121,125] nine at moderate risk of bias;[84,85,90,92,95,96,102,112,122] six at high risk of bias;[61,87,89,114,117,120] and fourteen were not rated due to the type of study design (data from audit-logs or qualitative studies).[45,73,74,82,97-99,106,115,116,118,119,123,124]

Level of Use and Primary Uses: Type of HIE

The majority of the studies used a variety of types of HIE, 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 HIE systems were noted for evaluations of the MidSouth e-Health Alliance (MSeHA),[40,86,99,118,119] the Central Texas HIE (I-Care),[54,101,103-105] the Health Care Efficiency and Affordability Law for New Yorkers Capital Grant Program (HEAL-NY),[97,98,102,125] and the Northeast Ohio Public Health Care System.[120]

Level of Use and Primary Uses: 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 (United States–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).[25,78-81,87] 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%).[81] 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.[87] The types of data most frequently exchanged were laboratory test results (84% to 90%),[78,81,87] inpatient data (70%), medication histories (70%), and outpatient data (60%).[78,81] 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),[79] while by 2012, there had been a 61 percent increase in the number of operational RHIOs, from 75 to 119.[25]

Two additional surveys were conducted by the eHealth Initiative [73,74] One-hundred, ninety-nine of 315 identified HIE organizations completed the 2013 annual survey. These HIE entities 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. HIE organizations are focusing on functionalities to support health care reform initiatives and advanced analytics.

The number of HIE organizations identified and that responded in 2014 was lower than in 2013, with 126 of 267 identified responding in 2014.[74] Again, there was a mix of community-based, State-based, and health care delivery organization-based HIE entities 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.[26]

Nine studies investigated HIE use retrospectively, using U.S.-wide survey data collected for other purposes, with an information technology add-on.[26,91,107-111,113] Four of these used data from the AHA,[26,107,108,111] two from the National Ambulatory Medical Care Survey, (NAMCS),[91,110] and one each from the Commonwealth Fund Health Policy Surveys,[109] the National Nursing Home Survey/National Survey of Residential Care Facilities,[111] and, another from the National Survey of Residential Care Facilities.[93]

These studies investigated overall participation in HIE use. Results suggest that HIE use by hospitals has risen from 11 percent (2009)[78] to between 30 percent and 58 percent more recently.[108,109,111] Results from the recently released ONC brief suggest that more than three-quarters (76%) of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with any outside providers in 2014. This represents an 85 percent increase since 2008 and a 23 percent increase since 2013. Close to seven in 10 hospitals (69%) electronically exchanged health information with ambulatory providers outside of their organization, representing a 92 percent increase since 2008 and a 21 percent increase since 2013.[26] Characteristics associated with higher use are nonprofit status, presence of an EHR system, larger market share, and larger practices.[107-109,111] 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.[91] Results from the NAMCS (2013) suggest that 39 percent of office-based physicians reported having HIE capability 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.[110] Data from the National Nursing Home Survey (2004) and the National Survey of Residential Care Facilities Survey, both from the Centers for Disease Control and Prevention, indicate that HIE use in these settings is low, with the consistent pattern of nonprofits enjoying wider use than for-profit entities.[113] Finally, recent data from the National Survey of Residential Care Facilities suggest that 23 percent of residential care communities that use EHRs also exchanged health information. Nearly 25 percent could exchange with pharmacies and 17 percent with physicians.[93]

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Adler-Milstein, et al., 2008[81]	U.S.-wide	RHIOs	Varies	Cross-sectional survey	Low	Participation in RHIO Types of data exchanged.	-Most common entities providing and receiving 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[78]	U.S.-wide	RHIOs	Varies	Cross-sectional 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[80]	U.S.-wide	RHIOs	Varies	Cross-sectional 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[79]	U.S.-wide	RHIOs	Varies	Cross-sectional 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[25]	U.S.-wide	RHIOs	Varies	Cross-sectional 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, et al., 2009[87]	U.S.-wide	RHIOs	Varies	Cross-sectional survey	High	Participation in RHIO.	-RHIOs: -12/20 (60%) are exchanging information -7/20 (35%) with Public Health -Type of data exchanged most frequently: Test results: 86%. -Public health agencies: -50 (36%) have no RHIO in jurisdiction. -16 (12%) have no relationship with RHIO. -26 (40%) are exchanging information.

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies) (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
eHealth Initiative, 2013[73]	U.S.-wide	All	Varies	Cross-sectional 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.
Swain, et al., 2015[26]	U.S.-wide	Non-Federal acute care hospitals and outside providers	Varies	Retrospective database analysis of AHA data	Low	HIE use between hospitals and hospitals; HIE use between hospitals and outside providers; Types of data exchanged (Labs, radiology, meds, clinical care summaries)	More than three-quarters (76%) of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with any outside providers. This represents an 85% increase since 2008 and a 23% increase since 2013. Close to seven in ten hospitals (69%) electronically exchanged health information with ambulatory providers outside of their organization, representing a 92% increase since 2008 and a 21% increase since 2013.

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies) (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
eHealth Initiative, 2014[74]	U.S.-wide	All	Varies	Cross-sectional 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[107]	U.S.-wide	Hospitals	Varies	Cross-sectional review of 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[108]	U.S.-wide	Hospitals	Varies	Cross-sectional Measurement of HIE usage among U.S. hospitals	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.

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies) (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Furukawa, et al., 2013[111]	U.S.-wide	Hospitals	Varies	Cross – sectional survey	Low	Participation HIE. Types of data exchanged. Characteristics of successful organizations.	-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.

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies) (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Patel, et al., 2013[91]	U.S.-wide	Ambulatory Care	Varies	Cross – sectional survey	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, et al., 2014[110]	U.S.-wide	Ambulatory care	Varies	Cross – sectional survey	Low	Participation in HIE. Characteristics of successful organizations.	-39% of office-based physicians reported having HIE capability 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[109]	U.S.-wide	Ambulatory care	Varies	Cross-sectional analysis of database	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.

Table 4. Level of use and primary uses of HIE: participation in HIE, types of data exchanged, and characteristics of successfully participating organizations (United States–wide studies) (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Hamann and Bezboruah, 2013[113]	U.S.-wide	Nursing Homes	Varies	Cross-sectional analysis of two survey databases	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.
Caffrey and Park-Lee, 2013[93]	U.S.-wide	National Survey of Residenti al Care Facilities	Varies	Cross-sectional survey	Low	Use of HIE among residential care communities that use EHRs	23% used computerized systems for exchanging health information with pharmacies; 17% with physicians; 20% with other health or long-term care providers, such as hospitals and nursing homes.

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.[82] 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.[116]

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, et al., 2011[82]	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, et al., 2014[116]	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.	-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 disclosers 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.

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 in HIE and Extent of Use: Regional or Statewide Initiatives

Nine studies described the use of HIE in the State of New York. Five of these used audit logs,[45,97,98,102,106] two used surveys,[76,77] one used a database of clinical data,[112] and one geo-coding[125] (Table 6). Most of the HIE implementations are query-based. The studies of audit logs indicate frequent queries,[97,98] and an increasing proportion of physicians accessing HIE over time (33% to 43% over 18 months).[45] 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.[106] 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,[97] while in another, 86 percent of sessions were with staff in an ED.[102]

Abramson et al. conducted three statewide surveys in New York, two in 205 hospitals[76] and the other in 632 nursing homes.[77] In each, they investigated participation in HIE and the exchange of data. In hospitals, their results suggest that between 2009 and 2012 the percent of respondent hospitals participating in HIE and exchanging data, increased from 23 percent to 79 percent. In 2012, institutions exchanged data more frequently with other hospitals (71%) and ambulatory care providers (69%), than with long-term care facilities (45%) and home health agencies (38%).[96] 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.[112] 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.[125]

A series of five studies investigated HIE use in a query-based Central Texas HIE. I-Care is an HIE implementation comprised of hospital systems, public and private clinics, and governmental agencies operating federally qualified health centers.[54,101,103-105] Four of these studies were conducted across several facility member sites, with a fifth study across two sites.[101] For adult patients seen in the ED, use was low; in 57 percent of patients[54] and only 2.3 percent of encounters.[105] 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.[101] Across these studies, HIE use was higher for those with a greater number of ED visits and hospitalizations,[54,101,105] older age, a greater number of chronic conditions,[101,105] females, and those with fragmented care.[101] HIE use was lower for blacks and Hispanics, visits for alcohol use, injury, poisoning, an unfamiliar patient, and a busier than average day.[105] 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.[104] 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.[103]

Of the five studies conducted in the MSeHA, based in Memphis, Tennessee, three used audit-logs,[40,99,118] one was a cross-sectional survey,[86] and one used mixed methods.[119] MSeHA is an HIE implementation 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.[40] In another, HIE was viewed in the ED for between 3 percent and 10 percent of visits.[99] 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.[118] 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.[86] 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.[119] Across these studies, use was higher when the HIE was accessed by nurses and clerks versus physicians.[99,118]

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.[83]

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.[84,85,88,90,92,100,120,123,124] These studies used data from 2005[123] through 2013.[90] Methods of data collection included surveys,[84,85,88,90,92,120] interviews,[85,124] focus groups,[123,124] and audit-logs.[100,120] 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.[88] Other Indiana investigators found real-time alerting helpful in prompting followup,[92] as did investigators in Louisiana.[124] Patients were generally accepting of data sharing, as long as patient benefit was evident.[124] 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.[85] 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.[90] 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.[123] 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.[100] In a description of HIE implementations 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.[84] 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.[120] 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 HIE 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 HIE and extent of use, by regional or statewide initiatives

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Abramson, et al., 2012[76]	New York State	Hospitals	Varies	Cross-sectional 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, et al., 2014[77]	New York State	Nursing homes	Varies	Cross-sectional 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%).
Abramson, et al., 2014[96]	New York State	Hospitals	Varies	Cross-sectional survey	Moderate	Use of HIE (sent or received). Type of institution information is shared with.	79% (n=102) of respondents reported actively exchanging any electronic patient-level clinical data with an entity outside their institution in 2012 vs. 60% in 2009 Institutions exchanged data with: Hospitals outside system: 71% (n=72) Ambulatory providers outside system: 69% (n=70) Long term care facilities: 45% (n=46) Home health agencies: 38% (n=39) Most commonly exchanged data were radiology reports, followed by laboratory results, medication lists and clinical histories.
Kern, et al., 2012[45]	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).

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Campion, et al., 2013[98]	Binghamton, New York	RHIO (2 hospitals and 13 ambulatory clinics)	Southern Tier HealthLink RHIO; Query	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, et al., 2013[97]	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.
Vest, et al., 2013[102]	Rochester, New York	RHIO (hospital and outpatient) and claims from health plans	Query	Case-control study of audit-log files	Low	Extent of use. Patient and provider characteristics associated with use of an 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.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Moore, et al., 2012[106]	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, et al., 2014[112]	New York	RHIO (ED)	Healthix	Cross-sectional database analysis	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
Onyile, et al., 2013[125]	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.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Vest, 2009[54]	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.
Vest, et al., 2011[104]	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.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Vest, et al., 2011[105]	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.
Vest and Jasperson, 2012[103]	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.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Vest, et al., 2012[101]	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, et al., 2008[99]	Tennessee	MidSouth e-Health Alliance (5 EDs)	Query	Multiple site case studies 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.
Bailey, et al., 2013[40]	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, et al., 2011[86]	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%)

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Johnson, et al., 2011[118]	Tennessee	MidSouth e-Health Alliance (12 EDs and 9 safety net clinics)	Query	Multiple site case studies, 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%).
Unertl, Johnson, and Lorenzi, 2012[119]	Tennessee	MidSouth e-Health Alliance (6 EDs and 8 ambulatory clinics)	Query	Multiple site case studies, 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[83]	6 states	HIE	Varies	Cross-sectional 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

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Kho, et al., 2013[88]	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, et al., 2012[92]	Indiana	Primary care physician offices.	Indiana HIE	Cross-sectional 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 followup call to patient vs. 4% sent attached letter
Fontaine, et al., 2010[85]	Minnesota	9 primary care practices with fewer than 20 physicians.	Not stated	Cross-sectional surveys & 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[90]	Minnesota	1,623 clinics	Varies	Cross-sectional 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.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Foldy, 2007[84]	Wisconsin	HIE organizations	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 HIE organizations 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, et al., 2007[100]	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.
Tripathi, et al., 2009[123]	Massachusetts	Massachusetts eHealth Collaborative	Not stated	Multiple site case studies, consumer 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%.

Table 6. Level of use and primary uses of HIE: participation in HIE and extent of use, by regional or statewide initiatives (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Herwehe, et al., 2012[124]	Louisiana	Louisiana Public Health Information Exchange	Not stated	Cross-sectional 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.
Kaelber, et al., 2013[120]	Ohio	Northeast Ohio Public Health Care System (10 hospitals and affiliated practices using Care Everywhere)	Query	Cross-sectional 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%)

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 Multinational Settings

Six studies that evaluate the use of HIE in non-U.S. settings met our inclusion criteria, one in Australia,[114] one in South Korea,[89] one in Scotland,[122] one in England,[121] two in Finland[61,115] (Table 7). Three multi-country studies,[94,95,117] two that included data from the United States,[95,117] comprise the last three studies in this group. 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.[89] Silvester and Carr found that commitment and interest in adoption increased over time.[114] Mäenpää et al. also found a steady increase in uses over time by physicians, nurses and administrative staff. [115] 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.[61] Investigating use in the National Health System in Scotland[122] and England,[121] Pagliari and Greenhalgh, respectively, both found use to be relatively low, although Pagliari's study is now older (2004). 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.[117] In a more recent study conducted in Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Switzerland, the United Kingdom, and the United States, Schoen found that the percent of primary care physicians reporting HIE capabilities ranged from a low of 14 percent in Canada to a high of 55 percent in New Zealand; use in the United States was reported to be 31 percent.[95] In a study that included the 27 European Union countries plus Croatia, Iceland, Norway, and Turkey, Codagnone used a factor analysis to create a composite metric that ranged between 0 and 4 to measure the extent of exchange of health information.[94] The metric suggested low to moderate use, with an average score across the 31 countries of 1.88. These early reports suggest that HIE in developed countries was in the initial stages of use in the early years of the 21st century, and is increasing slowly over time.

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

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Lee, et al., 2012[89]	Seoul, Korea	Hospital and 35 clinics	Not specified	Before-after 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, et al., 2009[114]	Brisbane, Australia	RHIO	Not specified	Before-after 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, et al., 2008[61]	Finland	RHIO	Not specified	Cross-sectional survey 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.

Table 7. Level of use and primary uses of HIE: extent of use, types of information exchanged, and adoption in international or multinational settings (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Mäenpää, et al., 2012[115]	Finland	RHIO	Not specified	Retrospective cohort of audit logs	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.
Pagliari, et al., 2004[122]	Scotland	Primary and secondary care	Varies	Cross-sectional survey and database review	Moderate	6 electronic deliverables: 1) outpatient booking; 2) referrals; 3) results reporting; 4) discharge correspondence 5) clinic letters; 6) clinic email	Access: To referral system (47%), results reporting (37%), outpatient booking (3%) Use: Results reporting (36%), referral (18%); clinic email (9%); outpatient booking (2%) Hospital wards able to send e-discharges: 10%; Wards generating and sending e-discharges: 7%; Surveys - of responding practices: Use of Lab results (93%); referrals (58%); discharges (42%); outpatient booking (16%). 90% reported daily or weekly use. Clinicians most common users of reporting/ referrals; Administrative /clerical staff most common users of discharge/ booking.

Table 7. Level of use and primary uses of HIE: extent of use, types of information exchanged, and adoption in international or multinational settings (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Greenhalgh, et al., 2010[121]	England	Primary care out-of-hours and walk-in centers	Varies	Cross-sectional database review and ethnographic field notes	Low	Use of the summary care record (SCR)	SCR accessed in 4% of all encounters; SCR accessed in 21% of encounters where an SCR was available; When available, clinicians accessed SCR 0% to 84% of time; main determinants of success were clinician characteristics (not specified);
Jha, et al., 2008[117]	U.S., U.K., Canada, Germany, the Netherlands, Australia, New Zealand	Physicians and hospitals	Varies	Cross-sectional, mixed methods literature review, surveys and interviews	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. The Netherlands: National 'SwithPoint' 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.

Table 7. Level of use and primary uses of HIE: extent of use, types of information exchanged, and adoption in international or multinational settings (continued)

Study	Geographic Location	Setting	HIE Type	Study Type	Risk of Bias	Outcome(s) Assessed	Results
Schoen, et al., 2012[95]	Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Switzerland, U.K., and U.S.	Primary care	Varies	Cross-sectional survey	Moderate	Ability to electronically exchange patient summaries and test results with doctors outside their practice	Percent of primary care physicians reporting HIE capabilities: Australia: 27% Canada: 14% France: 39% Germany: 22% The Netherlands: 49% New Zealand: 55% Norway: 45% Switzerland: 49% United Kingdom: 38% U.S.: 31% In the U.S. capacity for electronic exchange of patient information was concentrated in larger practices and those in integrated health systems (50% of physicians reported HIE vs. 23% of physicians not part of integrated practices p<0.05)
Codagnone, et al., 2014[94]	27 countries in the European Union plus Croatia, Iceland, Norway and Turkey	Varies	Varies	Cross-sectional surveys and interviews	Low	Factor analysis to reveal a composite measure of HIE use	On a scale between 0 to 4, Denmark score the highest (3.04), while the EU27 plus 4 scored 1.88.

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

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 22 studies of usability did not relate usability to effectiveness or harm.
- The evidence was insufficient to compare usability by type of function (query-based or pull vs. directed or pushed exchange) or by type of architecture (centralized or not).
- The most frequent users rated usability higher than infrequent users.
- Sites with proxy users (e.g., nurses, registrars) in the workflow reported the highest HIE use.
- The three most commonly cited barriers to HIE use were: lack of critical mass using exchanges (8 studies); inefficient workflow (10 studies); and poorly designed interface and update features (7 studies).
- Several facilitators showed promise in promoting electronic health data exchange: obtaining more complete patient information (6 studies); thoughtful implementation and workflow (12 studies); and well-designed user interface and data presentation (7 studies).

Detailed Synthesis

We identified nine multiple site case studies,[82,99,116,118,119,127-130] 11 cross-sectional studies,[58,62,86,94,131-137] and two before-after studies (Table 8).[138,139] Because these studies do not include a comparison with a non-HIE organizational site, risk of bias is not reported but is described when the details provided sufficient detail. No studies provided results on harm. All but five of the studies described experience with exchanging health information in the United States.[62,94,133,134,139]

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Bouhaddou, et al., 2011[82] Multiple site case studies of patient records, consent; usage.	Nationwide Health Informatics Network (NHIN) via CONNECT gateway allows users to pull in data from other organizations. The VA and DoD used the VLER systems for eHealth exchange with private sector. Transfer of records between integrated delivery systems; National query-based. Consent was opt in for the VA and Kaiser and opt out for DoD.	Patient identifier and demographic data, rates of consent	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, et al., 2014[116] Multiple site case studies. Quantitative data on Veteran participation and provider usage, interviews with both.	HIE between VA, DoD, non-Federal care organizations. The NHIN. 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 for the VA and Kaiser and opt out for DoD.	Veterans' authorization preferences, system dashboard. 73 provider interviews, 50 veteran interviews and documents from meetings	-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
Campion, et al., 2012[58] Cross-sectional survey of physician satisfaction with push vs. pull HIE	HealtheLink, 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%) vs. pull HIE (19%), (p=0.001). MDs more satisfied with push HIE than pull HIE ($p<0.05$).
Codagnone, et al., 2014[94] Cross-sectional survey and interviews of general practitioners using eHealth that included HIE.	Varies as this was an international survey	Survey of 9196 general practitioners who used computers in 31 European countries. 2 Focus group sessions.	From focus group sessions, authors reported on usability that HIE remains at the "transactional" level and doesn't yet support information sharing across healthcare tiers. There were quite a few general practitioners not yet using HIE. Additionally, concern about interoperability, lack of system resilience, lack of data standards and concern about security were barriers to adoption and use.

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Finnell and Overhage, 2010[131] Cross-sectional survey of EMS providers and analysis of use of HIE	Indiana Network for Patient Care (INPC). Community-wide EMR and active surveillance of reportable conditions, real-time electronic lab reporting. Query-based with a centralized model. Consent was opt out for both providers and patients.	Online survey responses from 58 of 180 invited medics (32% response rate), Database analysis of use of INPC per contact.	Over a six month study period, requests for patient data via HIE increased from 15% to 26% per patient contact. The majority of medics surveyed felt the HIE information was an important for delivering quality patient care, particularly for patients who can't communicate their health history. Medics who didn't use HIE cited network difficulties that delayed receiving the INPC abstract.
Gadd, et al., 2011[86] Cross-sectional survey of HIE use and usability	MSeHA in Memphis Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Query-based exchange with a decentralized system architecture with secure vaults managed by each organization. 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 ($p<0$ 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
Hincapie, et al., 2011[132] Cross-sectional, focus groups of physicians	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.
Hypponen , et. al, 2014[133] Cross-sectional survey of Finnish physicians on HIE success	Varied depending on type of regional health informational exchange system. Type 1: master patient index required separate login to centralized database. Type 2: web distribution model. Limited group of referring physicians could see hospital info. Type 3: regional virtual model. Clinician used an integrated system that includes all inpatient and outpatient information. Clinician has access to electronic patient record at other institution. Consent was opt in for Type 3.	Survey included 1693 physician respondents aged less than 65 years. 1079 specialized care; 614 primary care	Users of three local EHR systems preferred electronic HIE to paper to a larger extent than users of other EHR systems. Experiences with an integrated RHIE system (type 3) were more positive than those with other types or RHIE systems. Users of Type 1 reported lengthy log-in process and information took too long to receive. Recommended that HIE organizations address interoperability and interface issues, technical and data standards when designing system. Data format at one institution should be compatible with format of other institutions. Authors also commented that those who had access to all information via their own HER may not have realized that they were using HIE.

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Johnson, et al., 2008[99] Multiple site case studies. Quantitative analysis of audit-log files; qualitative analysis of feedback of system.	MSeHA in Memphis, Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Query-based exchange with a decentralized system architecture with secure vaults managed by each organization. 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
Johnson, et al., 2011[118] Multiple site case studies. Quantitative analysis of audit data; qualitative: semi-structured interviews and direct observations.	MSeHA in Memphis Tennessee. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Query-based exchange with a decentralized system architecture with secure vaults managed by each organization. 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%.
Kierkegaard, Kaushal and Vest, 2014[127] Multi-site case study. Qualitative, interviews with users and nonusers of HIE.	3 RHIO sites with query-based exchanges in New York: 2 federated models, 1 centralized model. Automated delivery of imaging and lab results to provider EHRs for two exchanges, automated CCD (one system). The one system that didn't have automated delivery included secure messaging and event (admission) notification	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.

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Machan, Ammenwerth, and Schabetsberger, 2006[62] Cross-sectional. Qualitative semi-structured, problem-centric interviews followed by cross-sectional survey on usage.	TILAK, health@net in Tyrol region of Austria. Transmission of discharge letters and clinical findings from hospitals to general practitioners. Direct exchange via email that was automatically integrated to physicians' computer system.	Interview with 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, et al., 2005[134] Cross-sectional satisfaction survey and 2 staff focus group sessions	Exchange in Adelaide, South Australia linking a public teaching hospital, ED and aged home-based care community services organization. When admitted to the hospital, the patient was added to a daily inpatient list received by the home-based providers who could log into secure website to run live reports of matched inpatients.	Satisfaction survey responses from 55 of 132 nurses, clinicians and allied health staff, 2 focus group sessions with 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.
McCullough, et al., 2014[135] Cross-sectional. Key informant interviews with stakeholders at practices and health centers	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. *This system was in implementation at time of study.*	24 interviews with clinicians, administrators, and office staff users	**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 nonvisit consults

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Messer, et al., 2012[138] Before-after study of organizational readiness to change, needs assessment interviews and pre-post quantitative survey of HIV provider users	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. Query-based exchange where each participating organization managed its own database.	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, et al., 2012[128] Multiple site case studies. Quantitative: emailed survey to current and intended users; qualitative: interviews with current HIE users during site visits	5 exchanges 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 nonclinicians 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 HIE 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.
Nohr, et al., 2001[139] Before-after Danish study that included survey and interviews on HIE expectation vs experience.	Four types were described: (1) common database; (2) Electronic Data Interchange via structured messages: copies of data are transferred between systems; (3) middleware: software between application and database; (4) internet technology: data communicated via browser.	Survey respondents: Expected benefits in 1998 (n=102); Experiences in benefits in 1999 (n=57); Expected barriers in 1998 (n=101); Experiences in barriers in 99 (n=99). Group interviews per site.	Several organizations have since started workflow analysis to identify former hidden procedures and for determining user requirements. One of the barriers was that most professionals used to the free-text nature of paper records and were now forced into structured format. One of the barriers was lack of knowledge about integration principles which left the vendors to provide solutions. One of the facilitators of success was a bottom-up approach with users involved during implementation. It is also helpful if the training go beyond basic use and provide information on becoming experts in using HIE. Finally, the organizations were unprepared technically to have a system running 24/7. They suggested having back up plans, e.g., mirrored databases.

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Ozkaynak and Brennan, 2013[129] Multiple site case studies. Direct observation, informal interviews during observation, formal semi-structured interviews with HIE users.	3 ED sites accessing the EDLinking system in Madison, Wisconsin. Clinicians can choose to use (or not use) the exchange.	210 hours direct observations, varied across shifts, in 5 rounds, informal conversations to followup on observations, 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.
Rudin, et al., 2011[136] Cross-sectional. Twenty interviews with clinician users, HIE staff and administrators	Massachusetts eHealth Collaborative. All nontext portions of medical record. Could link directly from the EHR to existing exchange. 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[130] Multiple site case studies. Interviews with ED physicians using HIE	HIE name not explicitly stated but may be MidSouth eHealth Alliance (MSeHA). 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.

Table 8. Summary of evidence addressing usability, barriers, and facilitators to use (continued)

Author, Year Study Design	HIE Description Type of HIE Patient Consent Process	Evaluation Data	Results
Unertl, Johnson, and Lorenzi, 2012[119] Multiple site case studies. Ethnographic study, direct observation, informal interviews during observation, formal semi-structured interviews with HIE users. Moderate 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.	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
Yeager, et al., 2014[137] Cross-sectional. Qualitative analysis of 16 interviews with healthcare stakeholders	LaHIE Hybrid, centralized and federated HIE in Louisiana that includes DIRECT messaging between providers. Providers can share CCDs, lab results, and electrocardiogram results.	Interviews with 16 healthcare representatives from organizations interested in joining LaHIE but not yet enrolled (n=4), not interested in joining (n=4), or already enrolled (n=8)	Five themes were identified related to usability. 1. Physicians found separate HIE logins required recalling separate passwords and delayed receiving information. Suggested having staff access HIE prior to visit and bring into patient chart. 2. Training is needed to get a critical mass of providers to contribute. 3. Quality of data in HIE is limited if some only provide discrete data. 4. Physicians expressed concern about liability if the HIE data isn't integrated into the patient chart.

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; LaHIE= Louisiana health information exchange; MD = medical doctor; MSeHA = Mid-South eHealth Alliance; NHIN = The Nationwide Health Information Network; RHIE= regional health information exchange; RHIO = regional health information organization; TILAK = Tiroler Landeskrankenanstalten; VA = The Department of Veterans Affairs; VLER = Virtual Lifetime Electronic Record

HIE Usability

Usability was 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." We found five surveys on HIE usability and most defined usability as it relates to function and/or measured satisfaction with exchanging health information.[58,62,86,133,138] One multiple site case study reported usability as composite measures of: ease of use and usefulness, described below for current and intended users of five HIE systems.[128] The composite score for perceived ease of use (which included level of agreement for 10 statements on use) averaged 3.9 on a 5.0 scale where 5.0 was "strongly agree."[128] 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 nonclinician 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.

Usability features were also examined in relation to actual use in one cross-sectional study of health care professionals electronically exchanging health data through the MSeHA.[86] 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 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.

HIE Satisfaction

Satisfaction with HIE, a measure of usability, was examined in one cross-sectional study[134] and one before-after study [138] One additional cross-sectional study that stratified satisfaction by types of HIE is described later.[58] 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.[138] Participants reported improved satisfaction with ease of data exchanged and improved patient care after using CAREWare software. The respondents also perceived that CAREWare was a good use of resources. They also reported improved relations with HIV care partners after implementing the RHIO. By contrast, before implementation, the providers had high expectations for how exchanging information would affect their work and reported some unmet expectations afterward.

In a second study on satisfaction of HIE users in Adelaide, South Australia,[134] users who embraced the use of the data exchange 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 an HIE system than infrequent users.[86] The response rate for the Massy-Westropp study was 24 percent (55 of 132).

While both satisfaction studies[134,138] provide descriptive evidence from surveys that users were satisfied with usability, neither provided sufficient details in the methods sections to eliminate bias or a comparison that would enable generalization.

Usability of HIE by Type

We also examined whether certain functionality (direct exchange or push vs. query-based exchange) was more usable. Directed exchange is provider-to-provider electronic exchange of patient information to coordinate care.[32] In this type of exchange, the data are electronically sent to the recipient's EHR or clinical inbox.[58] In query-based systems, the user accesses an exchange system, queries for information (e.g., ED, hospital admissions, or discharges) on a particular patient and pulls data from multiple health care organizations.[58] This is important particularly for unplanned care (e.g., patient comes into the ED).[13] We also attempted to evaluate usability by type of architecture (e.g., whether the query-based system used a centralized or federated model). However, few publications provided this level of technical detail to make a comparison. Additionally, the authors used a variety of terms and descriptions which made it difficult to classify usability by architecture. When the authors provided detail on architecture, it was included in Table 8.

Only one cross-sectional study evaluated clinician satisfaction with exchanging health information using query-based (pull) or direct exchange (push).[58] In this comparison study, clinicians had access to "pushed" health data (laboratory and radiology) through certified EHRs; physicians who ordered tests could designate other physicians to receive the test results. The physicians in this study could also query (pull), using a secure web portal, for test results, patient demographics and transcribed reports provided by physicians, hospitals, laboratories and radiology centers across the greater Buffalo and Rochester areas of New York. More providers reported using electronically pushed data exchange (80%) than pulled exchange of health information (53%). A greater proportion of physicians reported using pushed data exchange always or most of the time (68%) compared with pulled exchange (19%, $p=0.001$). The physicians were more satisfied when data were pushed than pulled ($p<0.05$).

In summary, we found insufficient data to compare usability by type or architecture of the electronic data exchange.

Facilitators and Barriers Impacting HIE Use

We identified many barriers and facilitators to electronic health data exchange in the literature. Evaluations of the MSeHA provide the most complete evidence on barriers and facilitators of use[86,99,118,119,130] but other studies echoed similar barriers.[62,82,94,116,127-129,131-133,135,136,139] 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 9).

Table 9. Barriers and facilitators of actual HIE use grouped by theme

Barriers	Studies of Barriers	Facilitators	Studies of Facilitators
Lack of Critical Mass • Patients concerned about privacy and security • Poor matching or patients • Providers stop using query-based system when can't find patients • Incomplete patient information • Patients outside of the HIE catchment area	Bouhaddau, et al., 2011[82] Byrne, et al., 2014[116] Hincapie, et al., 2011[132] Kierkegaard, Kaushal, and Vest, 2014[127] McCullough, et al., 2014[135] Ozkaynak and Brennan 2012[129] Rudin, et al., 2011[136] Thorn, Carter, and Bailey, 2014[130]	**More Complete Patient Information** • 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). • Consider when to push and when to pull data	Bouhaddou, et al., 2011[82] Byrne, et al., 2014[116] Campion, et al., 2012[58] Kierkagaard, Kaushal, and Vest, 2014[127] Messer, et al., 2012[138] Johnson, et al., 2011[118]
Inefficient Workflow • Separate login to portal – too many clicks. • Unmet expectations • Policy that prohibits proxy users • Need for more technical support • Need for culture change about practice	Byrne, et al., 2014[116] Hypönnen, et al,. 2013[133] Johnson, et al., 2011[118] Kierkegaard, Kaushal, and Vest, 2014[127] Machan, Ammenwerth, and Schabetsberger, 2006[62] Messer, et al., 2012[138] Myers, et al., 2012[128] Nohr, et al., 2001[139] Rudin, et al., 2011[136] Thorn, Carter, and Bailey, 2014[130]	**Thoughtful implementation and workflow** • Identify former hidden workflow • 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 • Implement a case management approach for HIE use • Have champion HIE users • Have sufficient technical support	Byrne, et al., 2014[116] Gadd, et al., 2014[86] Hincapie, et al., 2011[132] Kierkegaard, Kaushal, and Vest, 2014[127] Johnson, et al., 2008[99] Johnson, et al., 2011[118] Messer, et al., 2012[138] Rudin, et al., 2011[136] Thorn, Carter, and Bailey, 2014[130] Ozkaynak and Brennan 2012[129] Nohr, et al., 2001[139] Unertl, Johnson, and Lorenzi, 2012[119]

Table 9. Barriers and facilitators of actual HIE use grouped by theme (continued)

Barriers	Studies of Barriers	Facilitators	Studies of Facilitators
Poorly-designed Interface and Update Features • Too much information and slow response • Duplicate Information • Reports in exchange workflow may not meet needs of the provider • Competing use with existing patient portal with complete information • Lack of notes to set context in patient information • HIE not updated in real time	Hypönnen, et al., 2013[133] Codagnene and Lupiañez-Villanueva, 2014[94] Kierkegaard, Kaushal, and Vest 2014[127] Myers, et al., 2012[128] Thorn, Carter, and Bailey, 2014[130] Machan, Ammenwerth, and Schabetsberger, 2006[62] Rudin, et al., 2011[136]	**Well-designed Interface and Data Presentation** • Monitor quality of data against standards • Provide clear notifications of HIE • Send brief report first • Automatic integration with existing provider systems • Include providers and proxy users in design of interface	Bryne, et al., 2014[116] Hypönnen, et al,. 2013[133] Campion, et al., 2012[58] Kierkegaard, Kaushal, and Vest, 2014[127] Machan, Ammenwerth, and Schabetsberger, 2006[62] Thorn, Carter, and Bailey, 2014[130] Myers, et al., 2012[128]

HIE = Health information exchange; vs. = versus

Addressing Lack of Critical Mass

Concern was expressed in several studies about the need for a critical mass of users and populated patient information.[82,116,127,129,130,132,135,136] Underlying reasons for lack of critical mass can include several reasons (e.g., the providers aren't electronically exchanging the data or patients have not consented). Patients concerned with privacy and security may not understand the benefits 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.[132] 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.[132] Some contributing providers reported legal concerns for sharing patient data and may choose to not participate. The end result was that providers searching for patient information may grow frustrated at taking the time to search and stop using the system.

To increase the critical mass, several approaches have been suggested. These include addressing concern about privacy, careful consideration about the consent process, and a process for educating patients.[58,82,116,118,127,134,138] To address patient and provider concern about privacy, create clear understanding about privacy and data sharing among all stakeholders (providers, patients, nonclinician partners) prior to implementation.[138] In planning for electronic health exchange, several authors noted the importance of deciding whether to have opt out or opt in consent process for patients.[58,82,99,116,118,119,127,129,136] 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.[116] Opting in protocols seem to yield a high patient participation rate (93% to 97%).[58,127,136] When age is considered, older patients opt in more often than younger patients.[82] 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.[127] Additionally, patient awareness of provider use of the HIE may increase patients perception of the benefits of electronically exchanged data. Patients in the VA reported being unaware that providers were using the VLER system to access information outside of the VA.[116] The authors noted that the user interfaces of the VLER are not visible by patients because the display faces the providers. We identified one organization that used an opt out protocol (MSeHA).[118,119] Patients had the option to opt out at every encounter. The opt out rate was 1 to 3 percent,[118] which is slightly better than programs with an opt in protocol that lose 3 to 7 percent of patients who do not consent.[58,136]

Addressing Inefficient Workflow in Electronically Exchanging Data

Often the workflow was inefficient to providers attempting to exchange health information.[62,116,118,127,128,130,136,138] Users complained that additional logins and policies against proxy users increased the time the provider needed to access the patient information.

Sites with proxy users (registrars, nurses, clerks, and other physicians) who accessed the system and then provided the information to the attending physician had the highest access rates.[99,118] Proxy use was described as a way to save provider time or address needs of limited users without privileges.[130,132,136] Additionally, some organizations made it difficult to get privileges to access exchanged data so those with privileges were called upon to look up information for those without.[130]

An ethnographic qualitative study of the MSeHA identified two role-based workflow models: physician-based and nurse-based.[119] These investigators completed 180 observation hours of six EDs and eight ambulatory clinics using the MSeHA exchange 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 search for data 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 provider-based model, physicians and nurse practitioners searched for electronically exchanged information for more reasons than hospital visits. These providers browsed online medical history for purposes of decisionmaking. Finally, another study of the MSeHA reported that use dropped significantly after a new policy prohibited registrars from searching the system at the start of a visit.[118] Initially registrars would print off a summary sheet of available data. Providers then queried the system, based on the summary sheet. When a new policy came in place prohibiting registrars and nursing team members from accessing the system for security reasons, 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,[86,116] addressing needed culture change,[130] and having champion users.[99,127] One physician expressed in an interview that exchanging data is a change from practice. Physicians "get bogged down [with exchanging health information] and just want to see patients".[130] Introducing new technology requires addressing the need for change and the resistance that may exist. These studies also encouraged sites to manage expectations upfront[138] and have a pilot implementation prior to launch so users aren't disappointed.[118,132]

Addressing Poorly Designed Interface and Update Features

Several design features of the HIE created barriers to use.[62,116,127,128,136] While HIE users understood why textual notes were not exchanged for confidentiality reasons, this lack of context made the information less valuable.[136] 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. Some complained that the exchange contained too much information that was not filtered enough to be meaningful for providers.[127,128] They reported that reading a paper report was much faster than reviewing the exchanged information.[128] This finding was echoed by another study that recommended the main findings should be sent first in a brief report.[62] The design features could be addressed better at the implementation phase by including more providers during the design phase.[127] Another facilitator is to continually monitor the quality and usability of the exchanged data to meet standards and the needs of the users.[116] Similarly, as more patient data and more types of data were exchanged, users reported that their system response slowed suggesting the need to continually review (and reduce) what was being exchanged.[116]

Some users expressed concern with how quickly the patient information 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 exchange.[128] 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.[62,130]

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

Key Question 8. What factors influence sustainability of HIE?

Key Points

- There was a sizable body of research that attempts to identify and categorize the facilitators and barriers to implementation and factors that affect the sustainability of HIE (52 studies).
- This literature identified several categories of characteristics of HIE activities and organizations (internal factors) 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 lack of financial viability.
- The research cited policy and external environment influences as affecting implementation less frequently than internal factors.
  - Laws and mandates that require or support organizations engaging in HIE were the most frequently reported external facilitator for implementation.
- The most frequently cited negative influence on sustainability was competition that limited the necessary collaboration among organizations required to support HIE.
- Two key positive influences on sustainability were desire for the expected outcomes from HIE and the selection of HIE functions most likely to have financial benefits.

Detailed Synthesis

Both implementation and sustainability are organizational level measures of approaches to change. While the experiences, attitudes, and priorities of individuals may be important, ultimately the decisions to adopt and continue to support HIE activities are made by organizations not individuals. For this reason this section focuses on organizational level characteristics and factors that affect organizations' decisions and actions.

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 changing 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 52 studies that addressed implementation and/or sustainability (Appendix F). Fifty of the included studies were published in the past 8 years (2006 to 2014). Eight studies assessed HIE activities in countries other than the United States, 10 were based on U.S. national surveys or data, 10 covered multiple sites in the United States, but the most common were 24 studies that covered single State or regional HIE organizations and their efforts. Six of the studies were about HIE in New York, with five about statewide efforts or several RHIOs and one about New York City. Three were about HIE in California, but each study was about a difference regional HIE organization. No other State or metropolitan region was the subject of more than two studies.

Most of the studies were cross-sectional designs that collected data via surveys and interviews and relied on qualitative data analysis. More specifically 26 of the studies were cross-sectional,[79,84,85,87,94,100,108,124,140-157] 17 were multiple site case studies that compared experiences across different organizations or sites,[82,116,122,123,158-170] two compared outcomes before and after HIE,[114,138] three were retrospective cohorts,[43,44,48] two were prospective cohort studies,[171,172] and two were time series.[173,174] Almost half (23 of 52) of the studies used data from multiple sources, while the most common sole sources were interviews (10 studies) and surveys (9 studies). Other sources of data included databases (4 studies), audit logs (3 studies), and one each that used documents, organizational assessments, and a literature analysis.

Given the focus of Key Questions 7 and 8 and the sources of data it is not surprising that most of the analyses where qualitative (25 studies), including narrative summaries and the identification of themes. Twelve studies used quantitative analyses such as descriptive statistics, while seven employed more complex multivariate analyses. Eight studies combined qualitative and quantitative analyses (mixed methods).

Variety in study design, data sources, and analytic methods make assessing the quality across the 52 studies that address these Key Questions problematic. Quality assessment is frequently tied to risk of bias and the criteria are related to how the groups are constructed in cohort studies and how quantitative analyses are used to make these comparisons. While there are criteria for quality in other types of studies, these are used less frequently and there is not yet widespread agreement on the criteria, what is necessary to meet them, or what constitutes the difference between levels of quality. We can say that most of the studies in this section either attempted to include all sites or participants or included large samples of the population, increasing the likelihood that they are representative of the target populations. Also as we excluded purely descriptive studies, the qualitative analyses tended to follow established procedures (e.g., involvement of multiple researchers in coding) although in several cases the description of methods was limited.

One or more facilitator or barrier to implementation was identified in 42 studies while 17 studies reported factors related to sustainability. Some studies addressed by implementation and sustainability. We grouped the facilitators into eight categories and the barriers into seven categories created based on our interpretation of their similarities. These are described in the text below. In Tables 10 and 11 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,[43,144,164,174] prior experience with or readiness for IT projects,[138,158] preexisting membership in a network,[155] 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.”[158]

HIE Specific Structures

This category includes findings from seven studies and specific factors were goverance,[43] and participatory approaches that included efforts to encourage user engagement and stakeholder buy-in.[48,122,124,150,159] Examples include findings that involving users in development was key to implementation[150] and that a participatory process and shared decisionmaking permitted the HIE to address different values held by participants related to balancing individual rights and public health.[124]

Orientation Shift in HIE Organizations

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,[154] or from ownership of data to continuity of care that included realizing the value of external information.[170] Another important shift is from treating HIE activities as a pilot test to integrating them into a robust system integrated in workflow.[163] This research highlighted experiences that staying in the pilot phase for too long was detrimental to full implementation and increased use.

Design Characteristics

Cited as a facilitator for implementation in six studies. Studies found that a design that reflects an understanding of work flow,[150] and designs with smaller scale or more limited scope were more likely to be implemented.[169,173] The architecture and adaptability of information systems were cited as important design characteristics by two studies[161,169] 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."[161] An additional study found that successful HIE organizations used some existing standards rather than waiting for more universal standards that are under development.[159]

Key Functions

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.[85,114,116,169] One study concluded: "Implementation outcomes…were shaped substantially by the degree of attention dedicated to reworking procedures and practices so that HIE usage becomes routine."[169] Another study highlighted that addressing issues related to providing better quality data and integration into workflow allowed successful system-wide deployment.[116] However, the capacity for advanced use (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 development of a system that alerted providers to important patient events leading to both improvements in quality of care and contributing to organization goals such as medical home certification.[143]

Implementation Support

The need for an organization to provide resources to support the implementation of HIE was cited in the results of four studies. Specific types of support cited included technical assistance and training infrastructure,[114,167] the ability to do extensive testing for data quality,[154] and a comprehensive strategy for HIE activities and their implementation.[168]

Expected Outcomes

Two studies reported that specific expected outcomes were key to implementation. These included public awareness of the HIE[148] and link to a community need.[146] A third study highlighted the importance of establishing tangible intermediate goals in order to keep participants engaged and foster ongoing support.[159]

External Policy

Federal and State laws and mandates,[85,140,159] as well as grants,[158] were identified as facilitators in five studies when they promoted, required, or funded HIE director or foundational components such as EHRs. One study of 31 countries in Europe documented that HIE activities were more widespread in countries with national healthcare systems verses countries with social insurance systems.[94]

Table 10. Facilitators to implementation and sustainability of HIE

Facilitator	Number of Studies Reporting an Implementation Facilitator	Number of Studies Reporting Sustainability Positive Influences
General structure/organization*	**8**	**1**
Leadership	4[43,144,164,174]	
Prior IT initiatives or IT readiness	2[138,158]	
Network membership	1[155]	
Trust and solidarity	1[167]	
Able to innovate and react quickly		1[163]

Table 10. Facilitators to implementation and sustainability of HIE (continued)

Facilitator	Number of Studies Reporting an Implementation Facilitator	Number of Studies Reporting Sustainability Positive Influences
HIE-specific structure*	**7**	**3**
Participatory approach/user engagement/stakeholder buy-in	5[48,122,124,150,159]	
Governance	1[43]	
HIE lead by Health Information Organization		1[171]
Community needs assessment		1[171]
Marketing to patients		1[123]
Control over technology	1[163]	
Orientation shift*	**4**	
From competitive to collaboration	1[154]	
From ownership of data to continuity of care	1[170]	
To valuing contribution of external information	1[170]	
From pilot to robust system quickly	1[163]	
Design characteristics*	**6**	**3**
Information system architecture/adaptability	2[161,169]	
Smaller scale/limited scope	2[169,173]	
Reflect understand of services and work flow	1[150]	
Use of some existing standards while waiting for single standards in long term future	1[159]	
Select function likely to have financial benefit		2[147,160]
Key functions*	**5**	**1**
Make use routine/minimize burden and time/provide useful data	4[85,114,116,169]	
Advance use (decision support; medical home functions)	1[143]	1[147]
Implementation support*	**4**	
Comprehensive strategy	1[168]	
Extensive testing for data quality assurance	1[154]	
Technical assistance/training/change management	2[114,167]	
Expected outcomes*	**3**	**3**
Public awareness	1[148]	
Link to community need (public health use)	1[146]	
Tangible intermediate goals	1[159]	
Savings exceed costs		1[44]
Quality of care		1[153]

Table 10. Facilitators to implementation and sustainability of HIE (continued)

Facilitator	Number of Studies Reporting an Implementation Facilitator	Number of Studies Reporting Sustainability Positive Influences
External policy*	**5**	**1**
Laws and mandates	3[85,140,159]	1[140]
Federal and State grants	1[158]	
Type of Healthcare System (National, Social Insurance, transition)	1[94]	

HIE = health information exchange; IT= information technology
*Bold indicates overall category of facilitator.

Barriers

Barriers to HIE implementation cited in the research 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 policy,[164] the fragmented nature of funding (e.g., in public health HIE may be funded for some activities and not others),[157] and the uncertainty and the timelines for funding were seen as barriers.[143,174] One study identified the disconnect between State or Federal government goals and local realities as a significant barrier to HIE development.[166]

Disincentives

This is a broad category and the largest, including 20 studies. Four studies reported that competition for patients and the difficulty making the business case for HIE are important barriers,[108,142,151,155] and five additional studies more specifically cited the costs of HIE and the lack of financial viability.[85,108,141,158,167] In states with mature HIE implementations, where presumably the infrastructure was in place, participants cited costs and a lack of understanding of the value proposition as the major barrier to participation.[141] 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).[155,158,160] One study cited a trend to set up HIE that supported more administrative tasks over clinical tasks as a barrier.[94] Two additional studies cited insufficient resources.[84,87] In addition to financial and resource concerns, five studies identified concerns about data misuse, ability to protect privacy, and ethical issues related to sharing data.[124,142,148,160,165]

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.[85,174] 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.[149] 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.[148] Diversity and complexity within and across HIE systems were also cited as barriers. One study concluded that the extent of differences made sharing and applying lessons learned from one experience to another difficult[166] while another stated that many types of stakeholders and data result in levels of complexity that can impede implementation.[165]

Technology

The second most frequently cited (13 studies) category of barriers to implementation were issues related to technology. More specifically these barriers related to the technological environment. Two studies cited the lack of standards or differences in standards across organizations in the terms and definitions used in the data as well as the format of data sources.[87,172] Similarly three studies reported that interoperability across systems was an issue,[85,142,151] while three more studies specifically mentioned difficulties related to EHR interfaces that made exchange difficult or resulted in inappropriate or inaccuracy matching and merging.[143,154,167] Lack of system resilience, including operating speed and reliability was identified in a study of HIE activities in 31 European countries[94] while a study in the United States cited lack of information system capacity, particularly in smaller organizations. The authors of the study in European countries concluded, "we can pinpoint some clear bottlenecks in terms of 'electronically embedded' system inter-connection with other healthcare players, technical inter-operability, system resilience, and security.[…].Limited adoption of Health Information Exchange (HIE) is surely also a consequence of such bottlenecks."[94] 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."[48]

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.[84,141,154,158] 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.[154] One study focused on the challenges in securing data sharing agreements as a barrier to implementation.[143]

Fit

This is short hand for the correspondence between an innovation and the potential adopting organizations. Lack of fit is a 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.[152,167] 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.[100,145] One additional study underlined the fact that timelines were not realistic, particularly in cases where the technology was to be integrated into quality improvement activites.[143]

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,[141] and the need for training and expertise.[142,174] Two studies reported that user problems as fundamental as forgotten logons[145] and the technical performance of network connections hindered implementation.[116] One study reported corrupt data as a barrier to HIE,[172] while another reported the lack of tests that identify that the ability to match patients across systems were a barrier to development.[82] 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.[100]

Table 11. Barriers to implementation and sustainability of HIE

Barrier	Number of Studies Reporting Implementation Barriers	Number of Studies Reporting Sustainability Negative Influences
External policy*	**3**	**1**
Laws and regulations		1[162]
Changes in external (Federal, State) policy	1[164]	
Funding uncertainty and timelines	2[143,174]	
Disincentives*	**15**	**4**
Competition/difficult business case	4[108,142,151,155]	4[148,149,156,173]
Costs/financial viability	5[79,85,141,158,167]	
Organizations that invests does not benefit	3[155,158,160]	
Resources (funding and time)	2[84,87]	
Concerns about data misuse, privacy, or ethics	4[124,142,148,160]	
Structure*	**4**	**3**
Geographic coverage mismatch with service areas	1[148]	1[156]
Lack of leadership and management communication	2[85,174]	
Larger hospital systems (less need for external exchange)	1[149]	
Focus on long term care		1[171]
Governance/trust		2[153,156]
Technology*	**9**	**1**
Lack or differences in standards	2[87,172]	1[162]
EHR interface	3[143,154,167]	
Interoperability across systems	3[85,142,151]	
Problems with vendors	1[48]	
Lack of necessary components*	**5**	**1**
Participant/provider engagement, awareness of value	4[84,141,154,158]	1[146]
Securing data sharing agreements	1[143]	

Table 11. Barriers to implementation and sustainability of HIE (continued)

Barrier	Number of Studies Reporting Implementation Barriers	Number of Studies Reporting Sustainability Negative Influences
Fit*	**5**	
Inability or willingness to integrate into work processes	2[152,167]	
Lack of enough time for development and integration into Quality Improvement	1[143]	
Failure to meet expectations that data needs will be timely, complete and meet expectations.	2[100,145]	
User interface and functionality*	**8**	
Tech and HR resources to adapt software and processes	1[141]	
Need for training and expertise	2[142,174]	
Corrupt data	1[172]	
User interface and technical performance	2[116,145]	
Ability to match patients	1[82]	
Difficulty identifying provider to get alerts generated from HIE	1[100]	

EHR = electronic health record; HIE = health information exchange; HR = human resources; IT = information technology
*Bold indicates overall category of barrier.

Subgroup 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 so we were not able to consistently 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 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 17 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.[44,108,123,140,146-149,153,156,159,160,162,163,166,171,173] As HIE and health IT mature, a definition of successful sustainability may be developed and the evidence could them 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 for all but the organizations that were very early adopters of HIE.

We presented 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.

Ten included studies identified factors that are positive influences on sustainability. These included having an HIE implementation led by a health information organization as opposed to a health care organization[171] and having leadership and technology that allowed the HIE organization to innovate and react quickly to changes in the market and environment.[163] Sustainability was also linked to marketing the HIE to patients,[123] to how an HIE system incorporated a community needs assessment,[171] and if it selected functions likely to financially benefit the participants.[147,160] One study suggested that HIE implementations with advanced functions such as providing decision support are more sustainable[147] while another pointed out that these functions should add value related to either Stage 2 meaningful use or reform priorities in order to support sustainability.[159] Achieving important expected outcomes such as improved quality of care[153] and realizing savings that exceed the costs of the HIE system are understandably important[44] and one study described how most of the HIE organizations it examined are developing subscription fee structures to provide ongoing financial support.[159] One study reported that laws and mandates could promote sustainability as well as implementation of HIE. [140]

However, laws and mandates, particularly changes in these were also one of the reported negative influences on sustainability.[162,166] Four studies found that competition and a difficult business case for HIE were challenges to sustainability.[148,149,156,173] Four structural characteristics of HIE were also identified. These included the mismatch between the HIE geographic coverage and where patients receive services,[156] issues related to governance and trust among the HIE collaborators,[153,156] and one study found that HIE that focused on long-term care organizations were less likely to be sustainable.[171] 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.[162] Lack of sufficient engagement of participants and providers was also reported in one study.[146]

While there was 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.[156] Another suggested sustainability may become less a matter of availability of funds and more one of trust and responsible stewardship.[123] Combined, this result seems to be that sustainability of HIE activities is further in the future than many originally thought. As one observer noted “recent history suggests that achieving the kind of ubiquitous use among providers or other users that can drive a financial value proposition takes time—and likely more time than HIOs have modeled in their sustainability plans.”[163]

Discussion

Key Findings

- We found no studies of health information exchange (HIE) that reported the impact on clinical outcomes or that 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 was 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.
- Eight categories of factors facilitated HIE: seven cateogires that are internal characteristics while external factors were less frequently cited and we combined these into one category.
- Barriers identified in research on HIE implementation focused more on the external environment (7 categories). Disincentives was the largest category of barriers.
- Factors that influenced sustainability were similiar to the barriers and facilitiators of implementation. The most frequently cited negative influence was competition and the lack of a business case for HIE.

Key findings are summarized in Table 12.

Table12. Summary of evidence

Topic	Number of Included Studies Type	Main Findings	Primary Limitations of the Evidence
Effectiveness	34; 20 Retrospective cohort 3 Randomized controlled trial 2 Cross-sectional 2 Case series 8 Survey (1 survey study was an RCT)	Low-quality evidence somewhat supports the value of HIE for reducing duplicative laboratory and radiology test ordering, lowering ED costs, reducing hospital admissions (less so for readmissions), improving public health reporting, increasing ambulatory quality of care, and improving disability claims processing. No evidence of harms was reported.	Studies were from a small number of the functioning HIE implementations, with similarity to unstudied ones unknown, possibly limiting generalizability. Studies looked at limited outcomes compared with the intended scope of the impact of HIE.

Table12. Summary of evidence (continued)

Topic	Number of Included Studies Type	Main Findings	Primary Limitations of the Evidence
Use	58; 25 Surveys 13 Audit Logs 9 Retrospective database 7 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, 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.
Usability and other factors affecting use	22; 9 Multiple site case studies 11 Cross-sectional 2 Before-after	3 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 type 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	52; 26 Cross-sectional 17 Multiple site case studies 2 Before-after 3 Retrospective cohorts 2 Prospective cohorts 2 Time series	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.

ED = emergency department; HIE = health information exchange; RCT = randomized controlled trial

Strength of Evidence

Assessing the overall strength of the evidence for this review was 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-quality evidence somewhat supports the value of HIE for reducing duplicative laboratory and radiology test ordering, lowering ED costs, reducing hospital admissions (less so for readmissions), improving public health reporting, increasing ambulatory quality of care, and improving disability claims processing. The evidence is low-quality because of the retrospective nature of the studies and the limited questions that they ask. 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 was 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 have been 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 Coordinator[7] 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 the concentration of studies coming from a relatively small number of institutions.

The present systematic review of HIE can be compared with two other systematic reviews of HIE: one by Rudin et al.[32] and another by Rahurkar et al.[33] The three systematic reviews used generally similar approaches, with similar definitions of HIE and focus on studies of HIE impact, excluding system descriptions and simple case studies. The three reviews differ, however, in their scope and inclusiveness.

The review by Rahurkar et al. was most narrow in scope, addressing only the impact of HIE on “health outcomes,” in which the authors included utilization and cost measures. They searched two databases, Scopus and MEDLINE (along with reference mining), included non-U.S. studies, and excluded systematic reviews, qualitative studies, and studies of exchange of administrative and financial information.[33]

The review by Rudin et al. was broader.[32] In addition to health and utilization outcomes of HIE, they considered studies of patient and provider attitudes, barriers and facilitators to HIE use, and financial sustainability. These authors searched three databases, MEDLINE, Web of Science, and the Cochrane databases (along with reference mining), and they excluded studies of public health settings (included by Rahurkar et al.), administrative and financial information exchange, non-U.S. studies, and studies of usability.

Our review was the most broad in scope of the three, and the most inclusive in the search for evidence. In addition to patient and population health outcomes, economic, utilization process outcomes, and barriers and facilitators to implementation and use, our review also included studies concerned with use and usability of HIE. We also explicitly searched for reports of harms of HIE (although none were found). Our review was also more comprehensive in the search for evidence, searching MEDLINE, PsychInfo, CINAHL, the Cochrane databases, Database of Abstracts of Reviews of Effects, and the National Health Sciences Economic Evaluation Database, as well as reference mining. We also did trial scans of the Business Premier and the Institute of Electrical and Electronics Engineers (IEEE) *Xplore* Digital Library; databases for any potential relevant evidence. In addition, we included non-U.S. studies, and studies that reported on public health and surveillance uses as well as exchange of administrative and financial information.

The three reviews are based on comparable but not identical evidence bases. The present review includes a total of 136 studies. The review by Rudin et al. included 85 studies, 55 of which were also included in our review, and the review by Rahurkar et al. included 27 studies, 18 of which were also included in our review. We examined the references of both of these reviews and included any that met our inclusion criteria.

The overall result is that we examined a more diverse and more inclusive collection of evidence, especially with respect to usability and use as well as assessing public health settings, but came to largely similar conclusions. Rahurkar et al. performed a multivariable analysis that found that study design was the only characteristic associated with finding a beneficial effect, with the most rigorous studies being less likely to report benefits of HIE.

The problem of overlap across systematic reviews is an important one and has recently been addressed in the methods guides of the Cochrane Collaboration[175-177]and the Agency for Healthcare Research and Quality EPC program.[178] When large numbers of systematic reviews are conducted, there is inevitable overlap when two reviews are based on the same body of evidence. Additional reviews on a subject do not indicate more evidence on the question, only more thorough (when independent) examination of the same evidence.

A notable point to be made about the comparison between these reviews is that three 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 the level of confidence in the conclusions in that the three 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.

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 that: (1) 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) 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) 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 are typically 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. Related to this concern is a finding from other aspects of health IT,[176] namely clinical decision support, that systems evaluated by their developers tend to achieve more positive outcomes from their evaluation than external evaluators. This phenomenon must be assessed with HIE as well.

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.[179]

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.[32] 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.[180] 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 in general): (1) suitability of study design; (2) execution of the studies; and (3) 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.”[181] 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 possiblility 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.[179,182]

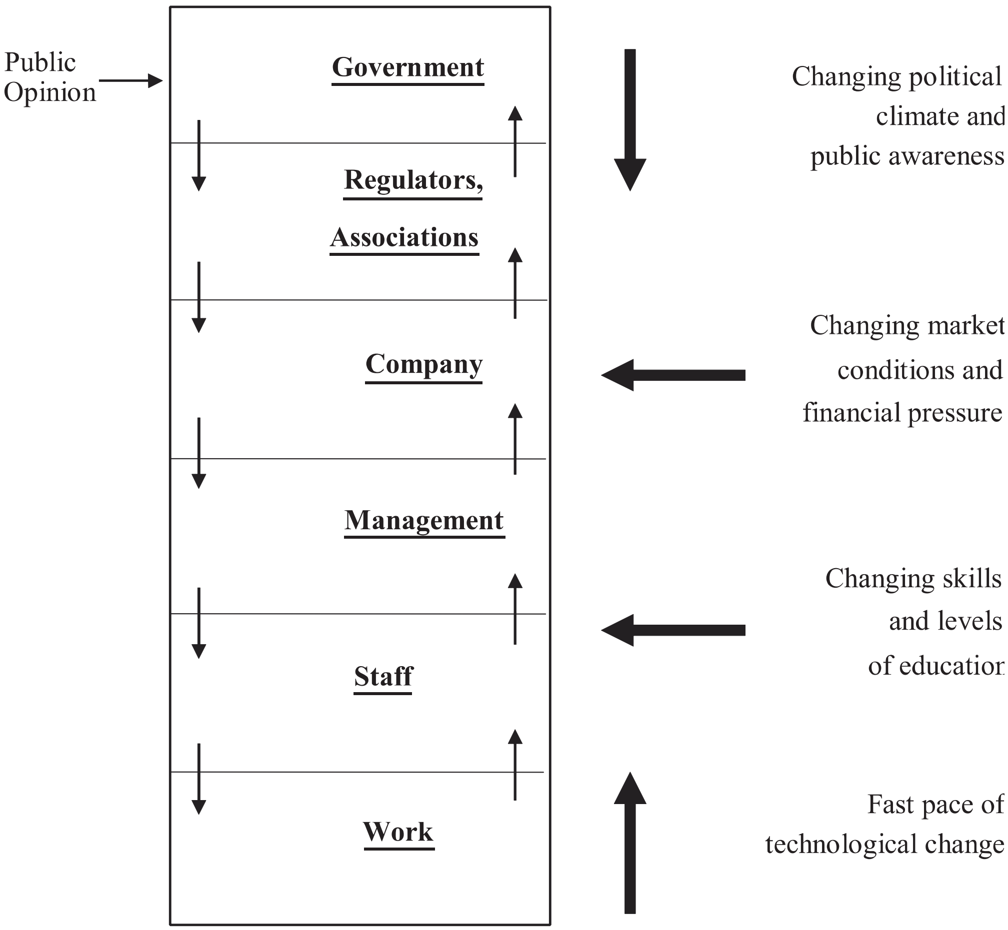
Future Research Needs

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 quesion 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 a more descriptive taxonomy are 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 of a complex sociotechnical system that must be considered together to understand system behavior change.[183] Examples of its application include Vicente’s analysis of the forces acting at multiple levels (Figure 3) to reduce hazards arising from patient controlled analgesia devices[184] and Leveson’s Systems—Theoretic Accident Modeling and Processes (STAMP) model for understanding system performance and safety.[185]

Figure 3. Rasmussen sociotechnical analysis framework* [184]



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Recognizing that one cannot understand a system by separately analyzing its parts, Rasmussen developed this analytical framework that encompasses the full range of dimensions that must be considered together to make sense of socio-technical behavior.

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.[179,187] This taxonomy should be extended specific to HIE to include clinical, technical, and organizational details of the HIE implementation. The clinical taxonomy should focus not only on patient outcomes, but also on issues such as health disparities related to HIE and health system issues that may improve or undermine use of HIE. The technical taxonomy should include aspects of system architecture, messaging and terminology standards, and other details. The HIE research community should consider a standardized reporting instrument for HIE evaluation comparable to the Consolidated Standards of Reporting Trials (CONSORT) statement for randomized controlled trials (RCTs).[188]

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."[189] Examples include infectious disease epidemiology, smoking,[189] and obesity.[190] 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.

What types of studies should be performed? RCTs are impractical for technologies with wide-ranging purposes like HIE. Yet, retrospective studies associating HIE versus non-use for outcomes such as test ordering and hospital admissions are very limited in conclusions that can be drawn. Research is also challenging because many of the important clinical outcomes that could benefit from HIE have many other potential contributing and confounding factors relating to the patient, his or her clinicians, the quality of care delivered, the electronic health record, and other health IT used, the nature of the health care delivery system, the regulatory environment, and many more.

Future studies should be prospective, carried out in mature HIE settings, assessing patients who are likely to benefit from HIE and comparing appropriate outcomes for the use or non-use of HIE. The prospective collection of data from diverse settings where HIE is used, classified by the taxonomy advocated above, could allow for prospective cohort studies that could identify aspects of HIE associated with beneficial outcomes. This will likely require an effort comparable in scope to national data collection efforts, such as the Patient-Centered Outcomes Research Institute Clinical Data Research Network initiative.[191] Ideally such an undertaking could be synergistic with these other large-scale efforts.

Evaluation should be a requirement for all HIE implementations, certainly those funded by grants or other external funding. The challenges of evaluating health IT projects, especially in community settings, is well-known,[30] but all funders must demand this requirement to grow the evidence base. By the same token, funders must provide adequate resources for such evaluations. In addition, evaluation should be performed by researchers external to the project to reduce potential bias from system developers evaluating their own implementations.[176]

Conclusions

The full impact of HIE on clinical outcomes and potential harms is insufficiently 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 increased 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
CHIC	Carolina HIV Information Cooperative
CI	confidence interval
CONSORT	Consolidated Standards of Reporting Trials
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
IEEE	Institute of Electrical and Electronics Engineers
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 Information Technology
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
STAMP	Systems—Theoretic Accident Modeling and Processes
TEP	Technical Expert Panel
VA	Veterans Affairs
VLER	Virtual Lifetime Electronic Record

Appendix A. Search Strategies

Database: Ovid MEDLINE® and Ovid OLDMEDLINE® <1990 to February 2015> Search Strategy

1 (health information adj5 exchang$).mp.
2 hie.mp.
3 exp Medical Records/
4 exp Systems Analysis/
5 exp Medical Informatics/
6 Information Dissemination/
7 3 or 4 or 5 or 6
8 2 and 7
9 1 or 8
10 health information organization$.mp.
11 7 and 10
12 (hio or hios or rhio or rhios).mp.
13 7 and 12
14 ((clinical$ or health$) adj5 (data adj3 exchang$)).mp.
15 7 and 14
16 (patient$ adj2 match$).mp.
17 7 and 16
18 ((query or querie$) adj3 (base or based or bases or basing) adj5 exchang$).mp.
19 7 and 18
20 directed exchang$.mp.
21 7 and 20
22 ((consumer$ or patient$) adj5 mediat$ adj7 exchang$).mp.
23 7 and 22
24 ((health information adj5 tech$) and exchang$).mp.
25 7 and 24
26 (health information adj7 network$).mp.
27 7 and 26
28 ((health information or ((electronic$ or computer$) adj2 (health or medic$ or patient$) adj2 record$) or ehr or emr) adj7 exchang$).mp.
29 7 and 28
30 (exchang$ adj5 network$).mp.
31 7 and 30 (116)
32 (interoperab$ adj7 standard$).mp. (320)
33 7 and 32
34 ((inter or between or across) adj3 (organization$ or systems) adj7 network$).mp.
35 7 and 34
36 9 or 11 or 13 or 15 or 17 or 19 or 21 or 23 or 25 or 27 or 29 or 31 or 33 or 35
37 Medical Record Linkage/
38 exp systems integration/
39 37 and 38
40 exp Cooperative Behavior/

41 37 and 40
42 exp Medical Informatics Applications/
43 37 and 42
44 10 or 12 or 14 or 16 or 18 or 20 or 22 or 24 or 26 or 28 or 30 or 32
45 43 and 44
46 36 or 39 or 41 or 45
47 6 and 38 and 42
48 6 and 38 and 40
49 4 and 37 and 40
50 4 and 37 and 42
51 6 and 37 and 42
52 6 and 37 and 40
53 4 and 38 and 40
54 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53
55 limit 54 to english language

Database: PsycINFO <1990 to February 2015> Search Strategy

1 ((healthcare information or health information) adj5 exchang$).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
2 exp medical records/
3 exp information systems/
4 exp Information Dissemination/
5 exp systems analysis/
6 exp information technology/
7 exp computer mediated communication/
8 2 or 3 or 4 or 5 or 6 or 7
9 hie.mp.
10 8 and 9
11 1 or 10
12 health information organization$.mp.
13 (hio or hios or rhio or rhios).mp.
14 ((clinical$ or health$) adj5 (data adj3 exchang$)).mp.
15 (patient$ adj2 match$).mp.
16 8 and 15
17 ((query or querie$) adj3 (base or based or bases or basing) adj5 exchang$).mp.
18 directed exchang$.mp.
19 ((consumer$ or patient$) adj5 mediat$ adj7 exchang$).mp.
20 ((health information adj5 tech$) and exchang$).mp.
21 (health information adj7 network$).mp.
22 ((health information or ((electronic$ or computer$) adj2 (health or medic$ or patient$) adj2 record$) or ehr or emr) adj7 exchang$).mp.
23 (exchang$ adj5 network$).mp.
24 8 and 23
25 (interoperab$ adj7 standard$).mp.
26 11 or 12 or 14 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 24 or 25

Databases: EBM Reviews - Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, NHS Economic Evaluation Database <1990 to January 2015>

Search Strategy

1 (health information adj5 exchang$).mp.
2 hie.mp.
3 ((health or medical) adj3 (record or records)).mp. [mp=title, text, subject heading word]
4 ((System or systems) adj3 Analysis).mp. [mp=title, text, subject heading word]
5 ((health$ or medic$) adj5 informatic$).mp. [mp=title, text, subject heading word]
6 ((informat$ or data) adj5 (link$ or disseminat$ or transfer$ or request$ or share$ or sharing)).mp. [mp=title, text, subject heading word]
7 3 or 4 or 5 or 6
8 2 and 7
9 1 or 8
10 health information organization$.mp.
11 7 and 10
12 (hio or hios or rhio or rhios).mp.
13 7 and 12
14 ((clinical$ or health$) adj5 (data adj3 exchang$)).mp.
15 7 and 14
16 (patient$ adj2 match$).mp.
17 7 and 16
18 ((query or querie$) adj3 (base or based or bases or basing) adj5 exchang$).mp.
19 7 and 18
20 directed exchang$.mp.
21 7 and 20
22 ((consumer$ or patient$) adj5 mediat$ adj7 exchang$).mp.
23 7 and 22
24 ((health information adj5 tech$) and exchang$).mp.
25 7 and 24
26 (health information adj7 network$).mp.
27 7 and 26
28 ((health information or ((electronic$ or computer$) adj2 (health or medic$ or patient$) adj2 record$) or ehr or emr) adj7 exchang$).mp.
29 7 and 28
30 (exchang$ adj5 network$).mp.
31 7 and 30
32 (interoperab$ adj7 standard$).mp.
33 7 and 32
34 ((inter or between or across) adj3 (organization$ or systems) adj7 network$).mp.
35 7 and 34
36 ((health$ or medic$) adj3 record adj7 (link$ or disseminat$ or transfer$ or request$ or share$ or sharing)).mp. [mp=title, text, subject heading word]
37 9 or 11 or 13 or 15 or 17 or 19 or 21 or 23 or 25 or 27 or 29 or 31 or 33 or 35 or 36

Appendix B. Inclusion and Exclusion Criteria

Table B1. Inclusion and exclusion criteria

	Include	Exclude
Population	All KQs: Any individual or group of health care providers, patients, managers, health care institutions, or regional organizations.	All KQs: Not applicable to a U.S. population.
Interventions	All KQs: Heath Information Exchange . HIE is defined as the electronic sharing of clinical information among users such as health care providers, patients, administrators or policy makers 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.	All KQs: Hypothetical HIEs, HIE within an organization/single setting, independent electronic prescription or referral system, a single person accessing multiple systems, registries, HIE for research, marketing or administration, non-electronic transfers.
Comparators	KQ 1-3: Time period prior to HIE implementations, geographic or organizational locations without HIE, situations in which HIE is not available, multiple types of HIE, characteristics of the different settings and systems in which HIE is used. KQ 4-8: No comparison required	KQ 1-3: No comparator KQ 4-8: None

Appendix C. List of Included Studies

Abramson EL, McGinnis S, Edwards A, et al. Electronic health record adoption and health information exchange among hospitals in New York State. J Eval Clin Pract. 2012;18(6):1156-62. PMID: 21914089.

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Appendix D. List of Excluded Studies

Report on community health information exchanges. Medicine on the Net. 2004;10(3):9-9.
Exclusion: Wrong study design

Connecting communities: making inroads to exchange electronic healthcare data at the local level. Qual Lett Healthc Lead. 2005;17(8):2-10. PMID: 16304880.
Exclusion: Wrong study design

Implementation of SNOMED-CT needed to facilitate interoperable exchange of health information. J AHIMA. 2005;76(9):30, 2.
Exclusion: Wrong study design

A primer for building RHIOs. Hosp Health Netw. 2006;80(2):49-56. PMID: 16572948.
Exclusion: Wrong study design

Health information exchange activities continuing to mature, says survey. Healthc Financ Manage. 2007;61(2):11.
Exclusion: Wrong study design

New computer network helps EDs to reduce redundant test orders: observers see significant savings, benefits in patient safety. ED Manag. 2008;20(12):133-4. PMID: 19086738.
Exclusion: Wrong study design

Wisconsin HIE optimizes community care. Communication among ED clinicians and federally qualified health centers in the Milwaukee area was improved, including real-time access to patient historical-encounter data. Health Manag Technol. 2009;30(12):28-9. PMID: 20043491.
Exclusion: Wrong study design

States with the most health information exchanges. Mod Healthc. 2009;39(27):32. PMID: 19606671.
Exclusion: Wrong study design

By the numbers. States with the most health information exchanges. Based on eHealth initiative's directory of health information exchange initiatives. Mod Healthc. 2010;40(14):34. PMID: 20402215.
Exclusion: Wrong study design

Physicians support health information exchange but are concerned about paying monthly fees. AHRQ Research Activities. 2010(359):14.
Exclusion: Wrong study design

Information exchange yields better decisions. ED Manag. 2010;22(9):103-4. PMID: 20853581.
Exclusion: No data relevant to a Key Question

Social Security report details $2 million return on HIE. For the Record (Great Valley Publishing Company, Inc). 2010;22(4):6.
Exclusion: Wrong study design

Findings from site visit to community clinic health network in san Diego, CA. Available at: http://aspe.hhs.gov/sp/reports/2010/chcit2010/SanDiego.html. Accessed November 10, 2014.
Exclusion: Wrong study design

States with the most health information exchanges. Based on ehealth initiative's map of health information exchange activity in the U.S. Mod Healthc. 2011;41(21):32. PMID: 21714447.
Exclusion: Wrong study design

By The Numbers: States with the most health information exchanges. Mod Healthc. 2011;41(21):32.

Exclusion: Wrong study design

High-tech approach to medication reconciliation saves time, bolsters safety at hospital in northern Virginia. ED Manag. 2011;23(10):117-9. PMID: 21972757.
Exclusion: Not HIE

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Exclusion: Wrong study design

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Exclusion: Wrong study design

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Exclusion: Not HIE

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Exclusion: Not HIE

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Exclusion: Wrong study design

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Exclusion: Not HIE

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Exclusion: Not HIE

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Exclusion: Not HIE

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Exclusion: Not HIE

Appendix E. Study Design Terminology

The studies included in this review are described in terms of their design, data source and analysis approach. Study designs are included in summary tables, while all three characteristics may be discussed in the text.

1) Study design:
    - Randomized controlled trial
    - Cohort (prospective or retrospective)
    - Case Control (be sure it actually is)
    - Cross-sectional
    - Time Series
    - Multiple site case studies
    - Case series
2) Data Source:
    - Database (administrative data, clinical data)
    - Survey, questionnaire, focus group
    - Audit logs
    - Observations
    - Documents
3) Analysis:
    - Quantitative
        - Descriptive statistics
        - Regression/Other multivariable analysis
    - Qualitative
        - Content or Thematic Analysis
    - Mixed methods
        - Includes quantitative and qualitative
    - Narrative description
    - Ethnographic

Appendix F. Evidence Table

Table F1. Evidence Table

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Abramson, *et al.*, 2012[76]	Cross-sectional	Measure EHR and HIE adoption in New York State hospitals	New York State	Hospital	**Survey of hospitals**	May-December 2009
Abramson, *et al.*, 2014[77]	Cross-sectional	Measure EHR and HIE adoption in New York State nursing homes	New York State	Nursing homes	**Survey of nursing homes**	November 2011-March 2012
Abramson, *et al.*, 2014[96]	Cross-sectional	To determine rates of participation in HIE	New York	Hospitals	**Survey responses**	November 2012 - February 2013

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Abramson, *et al.*, 2012[76]	Various HIEs around New York State	Type of data exchanged NR	NR	All 205 hospitals in New York State
Abramson, *et al.*, 2014[77]	Nursing homes around New York State	Exchange of data (NR) with pharmacies, lab, hospitals, physician offices, and RHIO	NR	All 632 nursing homes in New York State
Abramson, *et al.*, 2014[96]	NA	NA	NA	Surveyed Hospital IT directors or chief information officer

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Abramson, *et al.*, 2012[76]	Various HIEs	All hospitals in New York State	NA	None
Abramson, *et al.*, 2014[77]	Various HIEs	All nursing homes in New York State	NA	None
Abramson, *et al.*, 2014[96]	Contacted: 210 Hospitals Respondents: 129 (61.4%) Nonrespondents: 81 (38.6%)	All hospitals in New York state	NA	Results compared

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Abramson, *et al.,* 2012[76]	Participation in HIE	Participate in HIE (exchange of data)	NA	**Quantitative** Descriptive statistics
Abramson, *et al.,* 2014[77]	Participation in HIE	Participate in HIE (exchange of data)	NA	**Quantitative** Descriptive statistics
Abramson, *et al.,* 2014[96]	Use of HIE, if information is sent and/or received by the institution, type of institution information is shared with, barriers to implementation	NA	NA	**Descriptive statistics**

Author, Year	Results	Risk of Bias
Abramson, *et al.*, 2012[76]	23% of respondent hospitals participate and exchange data vs. 37% participate but do not exchange data vs. 40% do not participate	Low
Abramson, *et al.*, 2014[77]	54.4% participate in HIE, OR of participating in HIE: 2.26 more likely when have EHR **Exchange with providers when EHR** 59.7% within system vs. 31.3% outside system **HIE highest usage** Pharmacies: 41.8% Labs: 38.5% Hospitals: 38.5%	Low
Abramson, *et al.*, 2014[96]	-79.1% (n=102) of respondents reported actively exchanging any electronic patient-level clinical data with an entity outside their institution in 2012 vs. 60% in 2009 Type of institution respondents exchanged data with: Hospitals outside your system: 70.6% (n=72) Ambulatory providers outside your system: 68.6% (n=70) Long term care facilities: 45.1% (n=46) Home health agencies: 38.2% (n=39) The most commonly exchanged data were radiology reports, followed by laboratory results. Only 45 respondents (44.1%) exchanged medication lists and clinical history with hospitals outside their system. Respondents reporting participation in a regional arrangement for HIE: Any data exchange: 89.9% (n=116) Actively sending and receiving data: 50.9% (n=59) Sending data only: 25.9% (n=30) Receiving data only: 16.4% (n=19) Barriers to HIE participation reported by responding hospitals: Privacy concerns: 54.7% (n=70) Security concerns: 52.3% (n=67) Lack of IT staff to support HIE: 38.2% (n=49) Lack of architecture to support HIE: 35.9% (n-46) No differences in barriers among hospitals engaging in HIE and those not engaging in HIE were found. When hospitals engaged in sending and receiving data were compared with hospitals only sending or only receiving data hospitals only engaged in one activity were more likely to identify lack of architecture p=0.05 and cost of participating p=0.03 as barriers to HIE	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Adjerid and Padman, 2011[140]	Cross-sectional	-Analyze data from compilation of privacy laws and Adler-Milstein 2009 analysis of RHIOs -Examine association of state "consent prior to disclosure" laws with number of operational HIEs	U.S.	Any	**Survey** Data from compilation of privacy laws and Adler-Milstein 2009 analysis of RHIOs	2009-2010
Adler-Milstein and Jha, 2014[108]	Cross-sectional	-Analyze data from annual AHA survey of hospital IT -Measure HIE usage among U.S. hospitals	U.S.	Any	**Survey** Hospital survey database, augmented with market and other characteristic data	Late 2012
Adler-Milstein, Bates, and Jha, 2011[79]	Cross-sectional	Measure number of RHIOs, participation in them by ambulatory practices and hospitals, and number financially viable	U.S.	Any	**Survey of RHIOs**	June 2008-December 2009
Adler-Milstein, Bates, and Jha, 2013[25]	Cross-sectional	Measurement of types of data exchanged, organizations involved, and sources of financial support	U.S.	Any	**Survey of HIE organizations**	August-November 2012
Adler-Milstein, DesRoches, and Jha, 2011[107]	Cross-sectional	Measurement of participation in a regional HIO and exchange of data with hospitals or ambulatory providers of a different system	U.S.	Hospital	**Hospital survey database**	AHA survey from spring-summer 2009

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Adjerid and Padman, 2011[140]	All in U.S.	All types	NA	313 HIE initiatives from 2004-2009
Adler-Milstein and Jha, 2014[108]	All in U.S.	All types	NA	2,849 U.S. hospitals that responded to AHA IT survey
Adler-Milstein, Bates, and Jha, 2011[79]	All in U.S.	All types provided by a RHIO	NA	197 organizations meeting definition of RHIO
Adler-Milstein, Bates, and Jha, 2013[25]	All in U.S.	All types	NA	221 organizations facilitating HIE
Adler-Milstein, DesRoches, and Jha, 2011[107]	All in U.S.	All types	NA	3,101 acute-care, nonfederal hospitals that were U.S. based members of AHA

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Adjerid and Padman, 2011[140]	All 313 HIE initiatives	HIE status; state health disclosure law status	None	None
Adler-Milstein and Jha, 2014[108]	All of population	All hospitals responding to survey	None	None
Adler-Milstein, Bates, and Jha, 2011[79]	165 RHIOs	All RHIOs	Not meeting definition of RHIO	None
Adler-Milstein, Bates, and Jha, 2013[25]	NA	All organizations facilitating HIE	Organizations only participating in HIE	None
Adler-Milstein, DesRoches, and Jha, 2011[107]	Various HIEs	All acute-care, nonfederal hospitals that were U.S. based members of AHA	Hospitals that were federal or nonacute or were not members of AHA	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Adjerid and Padman, 2011[140]	Total, operational, and failed HIE	-Health disclosure law -Population -Per capita GDP	HIE size not accounted for	**Quantitative** Econometric models
Adler-Milstein and Jha, 2014[108]	Participating in HIE	-Ownership -Market position -Size -Teaching status -Cardiac ICU -System affiliation -Medicaid admissions -EHR system	NA	**Quantitative Multivariate Analysis** OR of likelihood of participation
Adler-Milstein, Bates, and Jha, 2011[79]	Operational RHIOs, supporting stage 1 meaningful use, ambulatory practices and hospitals participating in RHIOs, and number of financially viable	Operational RHIOs, supporting stage 1 meaningful use, ambulatory practices and hospitals participating in RHIOs, and number of financially viable	NA	**Quantitative**
Adler-Milstein, Bates, and Jha, 2013[25]	Operational exchange or data, types of data exchanged, barriers to exchange	Operational exchange or data, types of data exchanged, barriers to exchange	NA	**Quantitative** Descriptive statistics; compared with previous reports
Adler-Milstein, DesRoches, and Jha, 2011[107]	Participation in HIE and market characteristics	-Hospital profit status -Market share -Teaching status -Size -Cardiac ICU -System affiliation -Medicaid admissions -EHR system	NA	**Quantitative** Analysis of database Logistic regression models

Author, Year	Results	Risk of Bias
Adjerid and Padman, 2011[140]	States with stronger privacy laws have more operational HIEs, fewer failed HIEs, and take less time to reach operational status.	NA
Adler-Milstein and Jha, 2014[108]	-30% of hospitals engage in HIE, varying widely by state -For-profit hospitals less likely to engage than nonprofit hospitals. Hospitals with larger market share or in less competitive markets more likely to exchange	Low
Adler-Milstein, Bates, and Jha, 2011[79]	-75 operational RHIOs, covering 14% of U.S. hospitals and 3% of ambulatory practices -13 supporting meaningful use, covering 3% of hospitals, 0.9% of ambulatory practices; 67% not meeting criteria for financial viability	Low
Adler-Milstein, Bates, and Jha, 2013[25]	Predominant organization nonprofit; **Sources of support** Grants and contracts: 52%; participant fees: 28%; operating costs not covered by revenue: 57% **Barriers to development** Sustainability: 74%; lack of funding: 57%; privacy: 60%; mandates: 55%; technical barriers: 61%; competition: 56%; linking; 54%	Low
Adler-Milstein, DesRoches, and Jha, 2011[107]	10.7% participation in regional HIO; statistically significantly higher for private/nonprofit status, greater market bed share, teaching status, large size, cardiac ICU presence, and had EHR system	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Adler-Milstein, *et al.*, 2008[81]	Cross-sectional	Measurement of activities and financing of functioning RHIOs	U.S.	Any	**Survey of RHIOs**	July 2006-March 2007
Adler-Milstein, Bates, and Jha, 2009[78]	Cross-sectional	Measurement of types of data exchanged, organizations involved, and sources of financial support	U.S.	Any	**Survey of operational RHIOs**	2008, following up of survey from 2007
Adler-Milstein, Landefeld, and Jha, 2010[80]	Cross-sectional	Measure factors associated with becoming operational and achieving financial viability	U.S.	Any	**Survey of RHIOs**	Mid-2008
Afilalo, *et al.*, 2007[66]	RCT	Impact of sending family physicians electronic vs. mailed reports of ED visits for their patients	Montreal, Canada	ED and family physician practices	**Survey** Survey of family physician satisfaction	Not stated but likely same as Lang, 2006

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Adler-Milstein, *et al.*, 2008[81]	All in U.S.	All types provided by a RHIO	NA	138 organizations meeting definition of RHIO
Adler-Milstein, Bates, and Jha, 2009[78]	All in U.S.	All types	NA	207 organizations defined as RHIOs
Adler-Milstein, Landefeld, and Jha, 2010[80]	All in U.S.	All types provided by a RHIO	NA	131 organizations meeting definition of RHIO
Afilalo, *et al.*, 2007[66]	Adult university teaching hospital in Montreal	Report of ED visit sent to family physicians	NR	Patients visiting ED during 0800-2200

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Adler-Milstein, *et al.,* 2008[81]	32 RHIOs actively exchanging data	20 RHIOs actively exchanging clinical data for 5000+ patients	Not actively exchanging data	None
Adler-Milstein, Bates, and Jha*,* 2009[78]	All 44 operational RHIOs exchanging data for ≥5,000 patients	All RHIOs exchanging data for ≥5,000 patients	RHIOs not exchanging data or doing so for <5,000 patients	None
Adler-Milstein, Landefeld, and Jha, 2010[80]	81 RHIOs currently or planning to exchange data for 5000+ patients	81 RHIOs currently or planning to exchange data for 5000+ patients	Not meeting definition of RHIO	None
Afilalo, *et al.,* 2007[66]	2,022 (out of 3,168) patients visiting ED	Patients visiting ED	Patients in altered mental state (129), state of agitation (21), or with language barrier (29)	ED visit summary provided electronically vs. on paper sent by mail

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Adler-Milstein, *et al.,* 2008[81]	Proportion of RHIOs sending and receiving data to different entities and proportion exchanging specific types of data	-Entity sending data -Entity receiving data -Type of data exchanged	NA	**Quantitative** Descriptive statistics
Adler-Milstein, Bates, and Jha, 2009[78]	RHIO exchanging data for ≥5,000 patients	-Types of data -Entities exchanging data -Sources of financial support	NA	**Quantitative** Descriptive statistics
Adler-Milstein, Landefeld, and Jha, 2010[80]	Factors associated with becoming operational and achieving partial or full financial viability	-Participation -Types of data exchanged, focused on a specific population, history of collaborating, and sources of revenue	NA	**Quantitative** Multivariate logistic regression for predictors
Afilalo, *et al.,* 2007[66]	Physician attitudes on aspects of continuity of care for patients	Survey	Physicians already are sent carbon copies of first page of ED note; self-report of followup data	**Quantitative**

Author, Year	Results	Risk of Bias
Adler-Milstein, *et al.,* 2008[81]	**Entities providing data** Hospitals: 83%; ambulatory settings: 67%; labs: 60%; imaging results: 56% **Entities receiving data** Ambulatory settings: 95%; hospitals: 83%; public health departments: 50%; payers: 44% **Type of data exchanged** Test results: 90%; inpatient data test results: 90%; inpatient data: 70%; medication history: 70%; outpatient data: 60%	Low
Adler-Milstein, Bates, and Jha, 2009[78]	**Source of funding** Time or in-kind resources: 64%; recurring fee: 55%; grant: 48% **Types of data exchanged** Test results: 84%; inpatient data: 70%; medication history: 66%; outpatient data: 64% 28% of operational RHIOs expected to eventually cover operating costs **Barriers** Lack of funding, concerns about privacy/security, legal/regulatory changes, costs higher than expected, technical/infrastructure challenges	Low
Adler-Milstein, Landefeld, and Jha, 2010[80]	Likelihood of being operational associated with exchanging narrow set of data and involving broad group of stakeholders, likelihood of financial viability associated with involvement of hospitals and ambulatory physicians and early funding from participants. Financial viability diminished with early grant funding.	Low
Afilalo, *et al.,* 2007[66]	ED visits followed up by electronic reports led to family physicians having OR of higher rate of information receipt, more useful information, better knowledge of ED visits, better patient management, and more actions initiated by physicians. There was not perception of higher rate of followup in family practice offices.	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
AHRQ, 2006[166]	Multiple Case Studies	To describe current state HIE environment and analyze state HIE activities and initiatives.	National scan, in depth case studies of 8 States: Arizona, Florida, Hawaii, New York, North Carolina, Rhode Island, Tennessee, Utah	Multiple	Multiple Sources Literature reviews, web-based research, reports, interviews,	2005-2006
Altman, *et al.,* 2012[57]	Cross-sectional	To assess clinicians' impressions of an hourly notification of ED visit, hospital admission or hospital discharge with respect to the notifications effect on the continuity and coordination of patient care	New York	Family practice clinics	**Survey** Interviews	July 2011-October 2011
Anand, *et al.,* 2012[92]	Cross-sectional	Is real-time alerting useful and does it lead physicians to take action?	Indiana	Primary care physician offices	**Databases, questionnaire** Survey of value for real-time alerting for patient ED visit anywhere in state	June-November 2012
Audet, Squires and Doty, 2014[109]	Cross-sectional	Measurement of physician exchange of data outside of practice or to receive hospital discharge reports	U.S.	Physician offices	Surveys	March-July, 2012 (as well as comparison from data with 2009 survey, specific dates not provided)

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
AHRQ, 2006[166]	Varies	Varies	2003 to 2005	All HIE projects in US in 2055-2006
Altman, *et al.,* 2012[57]	New York Clinical Information Exchange (NYCLIX)	Hourly electronic notifications sent to family practice clinicians when any of 3 patient events occur at a participating hospital: (1) a new ED visit, (2) a hospital admission, or (3) a hospital discharge.	November 2010	Family practice clinicians in single health system receiving HIE notifications 86% MDs 50% male
Anand, *et al.,* 2012[92]	Indiana HIE (IHIE)	Patient data concerning ED visit	1994	Known physicians (538) of patients (1,275) seen in an ED for asthma
Audet, Squires and Doty, 2014[109]	All in U.S.	Physician exchange of data outside of practice or to receive hospital discharge reports	NA	1,012 primary care physicians in 2012

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
AHRQ, 2006[166]	101 HIE projects in 35 states for which information was available. 8 States for in depth case studies	HIE projects that included State and/or Medicaid involvement, targeted patients statewide or in large portions of the state, involve a RHIO or RHIO like organization	HIE projects within a single hospital or health system or that focused on administrative exchange or reducing fraud	Comparison of HIE project characteristics across states
Altman, *et al.,* 2012[57]	14 of 20 total	Clinicians receiving notifications	None	Changes in practice as perceived by interviewee
Anand, *et al.,* 2012[92]	79 physicians (10%) receiving 126 (15%) notifications	Physicians who had ≥1 patient seen in ED and faxed notification letter back to HIE	NA	Information helpful, resulted followup action
Audet, Squires, and Doty, 2014[109]	Various HIEs	Primary care physicians in U.S.	NA	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
AHRQ, 2006[166]	Number of HIE projects Similarities and differences among projects	NA	NA	Qualitative
Altman, *et al.,* 2012[57]	Usage logs of number of notifications sent to each clinician over a period of several months, questionnaires	NA	NA	**Thematic analysis** Themes of clinician perceptions identified and compared with recorded usage logs
Anand, *et al.,* 2012[92]	Rates of information helpful, resulted in followup action	Survey	None	**Quantitative** Descriptive statistics
Audet, Squires, and Doty, 2014[109]	Proportion of physicians exchanging data outside of practice or receiving hospital discharge reports	Proportion of physicians exchanging data outside of practice or receiving hospital discharge reports	NA	**Quantitative** Descriptive statistics and logistic regression

Author, Year	Results	Risk of Bias
AHRQ, 2006[166]	States have multiple HIE projects Project have similar goals but vary widely across other characteristics, particularly infrastructure which makes sharing lessons learned challenging Most projects are in early stages and have overly optimistic timelines Funding varies widely Sustainability is a long term goal but has not yet been realized. Most have not identified long term sources of funding While state are critical stakeholders many do not plan to play primary leadership roles indefinitely.	NA
Altman, *et al.,* 2012[57]	Notifications from an HIE system can enhance clinicians' awareness of their patients' interactions in the medical system. Clinicians perceived improvements in communication and followup scheduling as a result of notifications. Increase in clinician workload and change in responsibility may be unintended effects of notifications Workflow issues should be carefully considered. Timely notifications may further improve clinician-to-clinician communication	Moderate
Anand, *et al.,* 2012[92]	-35% found information helpful vs. 20% not helpful -24% made followup call to patient vs. 4% sent attached letter	NA
Audet, Squires, and Doty, 2014[109]	32% use of HIE, with higher proportion for formal IT support, part of integrated system, receiving financial incentives, larger practice	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Bailey, *et al.*, 2013[39]	Retrospective cohort	To determine whether HIE by ED personnel in the evaluation of patients with headache reduces use of neuroimaging, increases adherence with guideline	Memphis, Tennessee	ED	**Log file** Diagnostic neuroimaging, evidence-based guideline adherence	August 2007-July 2009
Bailey, *et al.*, 2013[40]	Retrospective cohort	To determine whether HIE reduces repeated diagnostic imaging and costs in ED back pain evaluation	Memphis, Tennessee	ED	**Log file** Administrative data for imaging log in patient record for HIE access	August 2007-July 2009
Ben-Assuli, Shabtai, and Leshno, 2015[72]	Retrospective cohort	Probability of single-day admission and 7-day readmission when HIE viewed	Israel	ED	**Log file**	2004-2007

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Bailey, *et al.,* 2013[39]	MidSouth e-Health Alliance (MSeHA).	MSeHA HIE connects 15 major adult hospitals and 2 regional clinic systems in 4 counties of the Memphis Metropolitan Statistical Area. Patient demographic, diagnosis, all hospital radiologic and laboratory reports, most procedure reports, and discharge summaries are exchanged. ED providers have read-only access to data.	2007	Patients presenting to participating EDs with principle diagnosis of headache
Bailey, *et al.,* 2013[40]	MidSouth e-Health Alliance (MSeHA), 15 major hospitals and 2 regional clinic systems in the 4 most populous counties of the Memphis Metropolitan Statistical Area. Decentralized, query-based exchange. Consent was ‘opt-out.	Secure, password-protected, read-only access to clinical information from participating hospitals and clinics through a Web portal separate from each facility’s electronic health record system. MSeHA HIE connects 15 major adult hospitals and 2 regional clinic systems in 4 counties of the Memphis Metropolitan Statistical Area. Patient demographic, diagnosis, all hospital radiologic and laboratory reports, most procedure reports, and discharge summaries are exchanged. ED providers have read-only access to data.	2007	All patients with an ED visit for back pain in the Alliance hospitals
Ben-Assuli, Shabtai, and Leshno, 2015[72]	Clalit HMO, Israel	Query	2004	All ED referrals

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Bailey, *et al.,* 2013[39]	2,101 2nd or subsequent visits for 1,252 patients	≥18years, a second or subsequent ED visit to a MSeHA participating general hospital's ED between August 1, 2007 and July 31, 2009 with a primary discharge diagnosis of primary headache disorder (ICD-9-CM codes 346.0, 346.1, 346.9 and 784.0); and no discharge diagnosis of stroke (ICD-9-CM 430–438), brain cancer (ICD-9-CM 191.x, 225.0 and V10.85), traumatic injury, motor vehicle accident, poisoning, or fall.	Primary diagnosis (ICD-9 codes) of variants of migraine (346.2), hemiplegic migraine (346.3), chronic migraine (346.7), other forms of migraine (346.8), and tension headache (307.81, 339.1) 1st visit for headache	None
Bailey, *et al.,* 2013[40]	Patients: 478 Visits: 800	≥18 years, >1 visit to system ED for back pain, index (previous visit) with imaging	Discharge diagnosis of trauma or cancer.	Repeat visits in which HIE was accessed vs. repeat visits in which HIE was not used
Ben-Assuli, Shabtai, and Leshno, 2015[72]	340,804 admitted and 474,310 non-admitted patients	Referred to ED and had a creatinine test	None	Access HIE information

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Bailey, *et al.*, 2013[39]	Use of diagnostic neuroimaging (CT, CT angiography, MRI or MRI angiography), evidence-based guideline adherence and economic	-Any HIE use -HIE use by physician or nurse practitioner -HIE use by administrative/nursing staff	nonuse of HIE	**Quantitative** Modeling using the generalized estimating equation method to adjust for repeated measures (since some subjects had >1 visit) and for clustering of subjects within hospital system
Bailey, *et al.*, 2013[40]	-Use of repeated lumbar or thoracic imaging -% cases HIE used -Cost	-HIE accessed by any ED staff during repeat ED visit (Yes/No) -Type of staff accessing HIE (MD or Nurse Practitioner vs. admin or nursing)	-Patient age, sex and race -Comorbidity -Hospital -Number of previous ED visits	**Quantitative** Chi^2 Multivariate: generalized estimating equation
Ben-Assuli, Shabtai, and Leshno, 2015[72]	Same-day admission and 7-day readmission	Access HIE information	None	**Quantitative** Same-day admission and 7-day readmission via logistic regression

Author, Year	Results	Risk of Bias
Bailey, *et al.*, 2013[39]	**OR (95% CI) of any HIE use** Neuroimaging: 0.38 (0.29 to 0.50) Adherence to guideline: 1.33 (1.02 to 1.73) -Increased odds of neuroimaging by subjects of older age, black race, and higher comorbidity -Prior visits lower the odds of imaging 7%, but the effect was reduced to 2% with use of HIE - No significant change in costs **Secondary analyses** -Administrative/nursing staff neuroimaging: OR 0.25 (95% CI, 0.18 to 0.34) -Physician/Nurse Practitioner HIE use and interaction terms for previous visits were not significantly associated -No secondary analyses were significant for guideline adherence	Low
Bailey, *et al.*, 2013[40]	Repeated imaging for any HIE: OR 0.36 (95% CI, 0.18 to 0.71), $p<0.05$ Visits with repeated imaging: 22.4% (179/800) HIE used: 12.5% -Physician or Nurse practitioner use of HIE lowered OR for repeat imaging OR 0.47 (95% CI, 0.23 to 0.96) - No cost savings associated with HIE use because of increased CT imaging when health care providers used HIE	Low
Ben-Assuli, Shabtai, and Leshno, 2015[72]	When external information viewed, probability of single-day admission decreased 9.5% and of 7-day readmission decreased 6.5%	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Ben-Assuli, Shabtai, and Leshno, 2013[41]	Retrospective Cohort	To determine whether HIE use was associated with reduced readmissions and "avoidable" admissions	Main Israeli HMO network	7 acute care hospitals EDs belonging to largest Israeli HMO	**Log file**	2004-2007
Bouhaddou, *et al.,* 2011[82]	Multiple site case studies with focus on identification of patients eligible, matching, and consent; usage	Across 3 large integrated delivery systems, how many patients can and will participate; how much used	San Diego, California	Integrated delivery system	**Database and survey** Patient identifier and demographic data	NR

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Ben-Assuli, Shabtai, and Leshno, 2013[41]	Largest Israeli HMO network 3.8 million patients, operates 7 hospitals	Clinical and administrative data from all HMO hospitals, community clinics and thousands of labs, imaging centers etc. Demographics, prescriptions, allergies, lab, imaging, past medical history, procedures.	2004	Adult patients presenting to Israeli ED with 1 of 5 main diagnosis; gastroenteritis, abdominal pain, chest pain, pneumonia organism, urinary tract infection
Bouhaddou, *et al.*, 2011[82]	Veterans Lifetime Electronic Record (VLER)	Query-based, transfer of records between integrated delivery systems	NR	Patients of 3 large IDSs who opted in to HIE

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Ben-Assuli, Shabtai, and Leshno, 2013[41]	115,719 ED Visits	NR	NR	HIE vs. local EMR and no EMR HIE vs. local EMR use
Bouhaddou, *et al.*, 2011[82]	1,144 patients shared between VA and KP Nationwide Health Information Network 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. Patient consent: Opt-in.	Patients identified as getting care in VA and KP	None	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Ben-Assuli, Shabtai, and Leshno, 2013[41]	-OR for 7-day readmission for gastroenteritis, abdominal pain, chest pain, pneumonia organism or urinary tract infection -OR for 1-day admission for gastroenteritis, abdominal pain, chest pain, pneumonia organism, or urinary tract infection -Economic	-MD Viewed EMR -MD Viewed local EMR -MD viewed external information (HIE) -HMO to which patient belonged -Differential Diagnosis -ED sub department (Int. med or surgical) -Specific Hospital -Age -Gender -Authors list all these variables as independent but some are more confounding per se	-Age -Gender -HMO -ED -Hospital	**Quantitative** -t test for continuous variables -Chi^2 for dichotomous -Multi-variate regression analysis -P<0.05, no adjustment for multiple hypothesis testing
Bouhaddou, *et al.*, 2011[82]	Patients who opted in and provided valid authorization, with subsequent measure of records exchanged between KP and VA 2-3 per week	-Patients correlated across KP and VA -Actual records exchanged	NA	**Quantitative** Survey, descriptive statistics

Author, Year	Results	Risk of Bias
Ben-Assuli, Shabtai, and Leshno, 2013[41]	**OR for all 5 differential diagnosis as composite** Readmission within 7 days: 0.52 for HIE vs. local EMR and no EMR, p<0.001 1-day admission: 0.76, p<0.001 Readmission within 7 days: 1.272, p=0.05 for local EMR vs. HIE 1-day admission: 1.13, p=0.005 for local EMR vs. HIE -Decrease in readmissions within 7 days when HIE used 56.1% -Decrease in single-day readmissions when HIE used 29.0% -Viewing external medical history more highly correlated with lower single-day admissions and 7-day readmissions than local medical history	Low
Bouhaddou, *et al.*, 2011[82]	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.	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Byrne, *et al.,* 2014[116]	Multiple site case studies	Describe key findings, lessons, implications from VLER pilot project	12 sites across U.S.	Unrestricted	**Audit logs, database, survey, interviews, documents from meetings** Veterans authorization preferences, system dashboard, VA provider (11/12 site) and veteran interviews. 73 provider interviews, 50 veteran interviews	December 2009-October 2012

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Byrne, *et al.,* 2014[116]	Veterans Lifetime Electronic Record (VLER)	Query-based HIE between VA, DOD, nonfederal care organizations. The Nationwide Health Information Network. The VA and DoD used the VLER systems for eHealth exchange with private sector. Federated pull model transfer of records between integrated delivery systems; 12 total sites, 4 did 3 way exchange, 8 did 2 way between VA and private sector. Federated pull model via eHealth Exchange	December 2009	Veterans

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Byrne, *et al.*, 2014[116]	12 pilot sites N=73 provider and 50 veteran interview	12 VLER pilot sites. Veterans included were any who opted in.	None	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Byrne, *et al.,* 2014[116]	-Veterans accept -Veteran concerns about participation -Veterans perceived benefit -Veteran awareness of VLER use during their care -Veterans preference of signed authorizations -Metrics of exchanged data	NA	NA	**Mixed Methods** Quantitative, descriptive analysis on usage; qualitative, thematic analysis

Author, Year	Results	Risk of Bias
Byrne, *et al.,* 2014[116]	-64,237 veterans provided authorization and opted in -Opted in then out: <0.01% -Veterans matched with exchange partner: 31,080 (48%), range: 12-88% -Highest matching rates with exchange partners using social security number in their algorithm -Inbound discloser's to VA from exchange partners 5,524 -Outbound disclosure to exchange partner 13,913 -Inbound disclosures to VA from exchanged partners per matched patients 18/100 -Unique VA patient with exchange partner data retrieved: 2,724 -Unique VA providers retrieving exchange partner data: 1,764 - Percent of matched veterans for whom there was ≥1 disclosure to VA from exchange partner: 9% -75% of providers trusted VLER data, 90% trusted privacy and security -Most frequently cited provider benefits, more data for medical decision making, improved quality of care, reduced repeat testing, timelier and faster access to information -23/73 interviewed providers reported using VLER, 79% of users reporting overall satisfaction -43% reported challenges with system response time, 29% with identifying patients who might have data -Identified minimizing provider steps in information retrieval, one site Indiana HIE had an automated query resulting in push into their system to allow providers pushed access anytime a patient was admitted discharged or transferred -Providers at outside organizations did not having additional sign ones -Workflow improvements suggested by outside users was to have data pushed in their EMR -Sustaining HIE requires ongoing resources and oversight, often unanticipated technical issues arose -Requires national policies and central coordination -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	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Campion, *et al.,* 2013[97]	Cross-sectional	Determine the extent to which automated HIE queries supported patient encounters.	Binghamton, New York	Hospital/clinic	**HIE log data**	2010 until 23 months following
Campion, *et al.,* 2012[58]	Cross-sectional	What is usage and satisfaction of push and pull HIE	Buffalo and Rochester, New York	Health systems, health departments, practice associations, RHIO	**Survey** Online survey responses from 112/584 invited physicians (19% response rate)	July-December 2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Campion, *et al.*, 2013[97]	Southern Tier HealthLink RHIO in Binghamton, New York part of SHIN-NY. Automated queries occurred evening prior to ambulatory patient appointments to generate CCRs and for the hospitals during ED visits, at inpatient admission, inpatient unit transfer and provided CCD doc to providers. Providers could also log in manually. Auto queries started month 1 for clinics and month 17 for hospitals.	Lawson Cloverleaf HIE, centralized data repository with MPI. 5 hospitals, one imaging center and 30 ambulatory care practices affiliated with single integrated delivery system.	2005	≥18 years, with positive consent to participate in HIE
Campion, *et al.*, 2012[58]	HealtheLINK (Buffalo) and Rochester 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. Robust RHIOs using HIE platform from Axolotl Corporation (San Jose, California)	2007-2009	Physicians

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Campion, *et al.,* 2013[97]	202,365 auto queries	≥18 years, who had automated HIE query generated, which occurred when a care transition occurred	Lack of known provider or lack of known facility in auto-queries from HIE	NA
Campion, *et al.,* 2012[58]	112/584 invited physicians (19% response rate). Only 99 completed. 75% were primary care providers. Most practices had 2-19 providers.	Physicians who completed survey and rated overall outcome of satisfaction with HIE	Respondents who did not rate satisfaction with HIE	Compared various attributes of HIE for push vs. pull

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Campion, *et al.*, 2013[97]	Generation of automated HIE queries	NA	NA	**Quantitative** Descriptive statistics
Campion, *et al.*, 2012[58]	Use of push vs. pull HIE. Satisfaction with types of HIE.	Type of HIE: push or pull	NR	**Quantitative** Descriptive statistics

Author, Year	Results	Risk of Bias
Campion, *et al.*, 2013[97]	-202,365 automated HIE queries: 54% to hospitals, 46% to clinics -After exclusions, duplicates removed: 145,668 unique patient encounters -81,687 unique patients provided consent for query based HIE during study period, 41% had ≥1 supported encounter -For the 33,219 patient with ≥1 clinic encounter: median IQR 3 -98% of patients had between 1 and 20 encounters, 71% had ≥2 -530 patients with ≥20 encounters -52% occurred in hospital, 48% in clinics **Care Transitions** -28% of the 145,668 unique encounters occurred as care transitions -53% were patients from a clinic to hospital, 36% in reverse, 11% clinic to clinic	NA
Campion, *et al.*, 2012[58]	-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%) vs. pull HIE (19%), p=0.001 -MDs more satisfied with push HIE vs. pull HIE, p<.0.05 -112 physician respondents (19% response), 13 then excluded for 99 participants ->50% of physicians felt HIE improved 8 domains; access to timely, completeness, accurate information, admin efficiency, communication with colleagues, and quality -Only 30% felt it improved reducing test redundancy and security of PHI -Physicians who used push and pull vs. only single type had higher rates of perceived effects of HIE in same 8 domains, (3of 8 domains p<0.05)	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Campion, *et al.,* 2013[98]	Cross-sectional survey	Measure usage patterns of query based HIE with respect to practice sites, users, patients, and data	3 separate RHIOs encompassing 1 community each (~1 million patient population) in New York state (from HEAL-NY)	Unclear, inpatient/ outpatient	**System log data** Demographics of patient, provider character (i.e. role, location etc.)	A, B: January 2009-March 2011 C: September 2010-May 2011
Caffrey and Park-Lee, 2013[93]	Cross-sectional	To determine use of EHR and HIE by residential care communities.	U.S.	Residential care communities	**Survey** 2010 National Survey of Residential Care Facilities	2010
Carr, *et al.,* 2014[70]	Case series	Does HIE reduce unneeded test ordering and costs, admissions	Charleston, South Carolina	ED	**Questionnaire** User-initiated survey, with costs calculated for self-reported testing not performed	August-December 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Campion, *et al.,* 2013[98]	NY State HIE consists of 12 RHIOs (HEAL NY)	Axolotl Virtual Health Record-commercial product. Web based secure stand alone portal. Federated architecture with MPI, RLS and user directory.	2007, 2007, 2010; A, B and C, respectively.	All patients
Caffrey and Park-Lee, 2013[93]	NR	NR	NR	Residential care communities
Carr, *et al.,* 2014[70]	Carolina eHealth Alliance	Access to EHRs and ED from all hospitals in region	NR	Physicians, Nurse Practitioners, Physician Assistants, and students

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Campion, *et al.,* 2013[98]	Combined 2.9 million total patients in 3 RHIO communities	All patients	None	NA
Caffrey and Park-Lee, 2013[93]	Sampled: 3,605 Interviewed: 2,302	Residential care communities that have been licensed, registered, listed, certified or otherwise regulated by the states with >4 beds, >1 resident currently living in the community, and provide room and board with at least 2 meals a day, around the clock onsite supervision, and help with personal care such as bathing and dressing or health=related services such as medication management.	Communities licensed to serve severely mentally ill or intellectually or developmentally disabled populations exclusively. Nursing homes were also excluded unless they had a unit or wing meeting inclusion criteria where residents could be enumerated separately.	NA
Carr, *et al.,* 2014[70]	18,529 patient encounters, with 998 logons (5.39%) by 60 clinicians. 138 (13.8%) surveys completed. 105 (10.5%) of patients had data in HIE.	All survey responses from HIE users	NA	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Campion, *et al.,* 2013[98]	-% practice sites accessing data -Type of practice accessing HIE -Number of roles and primary practice of users accessing HIE -Characteristics of patients whose data was accessed -Consenting of patients related to access	NA	NA	**Quantitative** Descriptive statistics
Caffrey and Park-Lee, 2013[93]	% of residential care communities that used EHR with computerized support for HIE	NA	NA	**Quantitative** Regression
Carr, *et al.,* 2014[70]	-Services, costs, and admissions avoided -Perceived time saved	Tests, costs, and admissions avoided	NA	**Quantitative** Self-reported tests and admissions avoided, calculation of costs saved based on local data.

Author, Year	Results	Risk of Bias
Campion, *et al.*, 2013[98]	A vs. B vs. C -Of sites registered to use system: 18% vs. 30% vs. 82% accessed in first 9 months -After 27 months 60% vs. 59% vs. NR of sites had accessed -In each community majority of practice sites from which access occurred were out patient -In A and B majority of sessions were from outpatient sites, C was inpatient -Registered users in community: 368 vs. 3461 vs. 118 -More than 1/2 users accessing system in A and B were nurses + staff, in C 2/3 were MDs + physician extenders -Majority of all users practiced in ambulatory setting -Patients whose data was accessed were older than those whose was not and then the entire population -For community A&B majority had data accessed on same day as consent -Majority of patients in A and B had their data accessed in community setting, C was inpatient -% of patient whose data was accessed from ≥2 sites in first 9 months: 0.1% vs. 1.8% vs. 0.01%; after 27 months: 0.1% vs. 11.6% vs. NR -System access occurred from 60% to 82% of practice sites registered to use system, depending on community -Proportions of patients whose data were accessed varied between 5%-60% -Most frequently accessed data were patient summaries, followed by lab and radiology data	NA
Caffrey and Park-Lee, 2013[93]	17% of residential care communities reported using EHR **% of residential care communities using EHR with computerized system to support HIE by provider type:** Any provider: 40 Pharmacy: 23 Other health or long-term care provider: 20 Physician: 17 Corporate office: 17 Other: 17	Low
Carr, *et al.*, 2014[70]	-Reported avoiding: 30.5% lab/micro tests ($462), 47.6% radiology tests ($161,000), 19% consultations ($4,000), 11.4% admissions ($118,000) -86.7% reported improved quality of care -81% reported time savings, averaging 120.8 minutes	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Chang, *et al.,* 2010[51]	Cross-sectional	Development and evaluation of enhanced reporting of lab data based on data available to HIE	Indiana	Physician office, outpatient	**Survey** Survey of physicians who were potential users of reporting interface	2 week period in 2007
Codagnone and Lupiañez-Villanueva, 2013[94]	Cross-sectional	To measure and explain levels of availability and use (adoption) of eHealth applications and services	31 countries: EU27 countries plus Croatia, Iceland, Norway and Turkey	Varies as this was an international survey	**Survey, interviews, focus groups**	October 25, 2012 to March 6, 2013
Dixon, Miller, and Overhage, 2013[141]	Cross-sectional	What are barriers to participation in a mature state HIE?	Indiana	Small hospitals, small physician practices, and large physician practices	**Survey and interviews** Initial mixed methods interviews with most physician groups given online survey	August 2009-March 2010
Dixon, Jones, and Grannis, 2013[83]	Cross-sectional	Awareness and engagement of infection preventionists in HIE for public health surveillance	6 states with HIE - 3 funded by CDC for explicit HIE-based reporting and three with mature HIEs	Case reporting for public health reporting of notifiable conditions	**Survey** Online survey of 63 infection preventionists	NR

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Chang, *et al.,* 2010[51]	Indiana Network for Patient Care	Collection of all lab data with enhancements (prior results, other historical lab results, prescriptions, encounters), pharmacy data, and patient encounter data	Not stated, but in 1990s	Primary care physicians who were users of HIE
Codagnone and Lupiañez-Villanueva, 2013[94]	Varies as this was an international survey	Varies as this was an international survey	Varies as this was an international survey	Random sample of general practitioners who use a computer
Dixon, Miller, and Overhage, 2013[141]	Indiana HIE (IHIE)	Full medical record in HIE	1994	Small hospitals, small physician practices, and large physician practices in Indiana who were not participating in HIE
Dixon, Jones, and Grannis, 2013[83]	6 states with mature HIEs but details not explicitly provided	6 states with HIE — 3 funded by CDC for explicit HIE-based public health surveillance reporting for infections, versus three with mature HIEs, but without active surveillance reporting. 63 preventionists.	Not specific, would be variable by state	Infection preventionists

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Chang, *et al.,* 2010[51]	NA	Convenience sample of primary care physicians	NA	None
Codagnone and Lupiañez-Villanueva, 2013[94]	9,196 general practitioners	General practitioners who use a computer	General practitioners who don't use a computer	Comparison of HIE use by country to prior survey in 2007
Dixon, Miller, and Overhage, 2013[141]	12 small hospitals, 20 small physician practices, and 11 large physician practices who were not participating in HIE	Small hospitals, small physician practices, and large physician practices in Indiana who were not participating in HIE	Small hospitals, small physician practices, and large physician practices in Indiana who were participating in HIE	Barriers of cost, lack of sufficient technical or human resources, or lack of awareness regarding value proposition
Dixon, Jones, and Grannis, 2013[83]	NA	Infection preventionists in public health departments in 6 states	NA	Comparisons in states with active public health surveillance vs. those without

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Chang, *et al.,* 2010[51]	Evaluation of developed report	Various factors related to usefulness and completeness	NA	**Quantitative** Satisfaction survey
Codagnone and Lupiañez-Villanueva, 2013[94]	Use of 15 functions of HIE and 4 functions of telehealth. Comparison with previous survey in 2007.	Country, Types of HIE use	Addressed thoroughly in multiple analyses of use and adoption.	**Quantitative multivariate analysis** Factor analysis to create 1 overall composite indicator, and 4 smaller composite indicators (EHR, HIE, telehealth, PHR). Comparison with 2007 results.
Dixon, Miller, and Overhage, 2013[141]	Barriers of cost, lack of sufficient technical or human resources, or lack of awareness regarding value proposition	Survey	None	**Mixed methods** Qualitative content analysis of interviews and quantitative tabulation of surveys
Dixon, Jones, and Grannis, 2013[83]	-EHR use -EHR involvement in implementation -Involvement in HIE -Method for notifiable case reporting	-Organizations with EHR -Involved in implementation of EHR -Engaged in HIE -Reporting methods for notifiable cases	NA	**Quantitative** Descriptive Statistics

Author, Year	Results	Risk of Bias
Chang, *et al.,* 2010[51]	-9 physicians sampled -Average 5 point Likert scales reported showed perception was generally favorable. ELRs well organized (4.2±0.97) and easy to interpret (4.3±0.50). Additional data elements were valuable: relevant test (4.2±0.97), contextual drugs (4±0.89), visit histories (3.25±0.71) and computer generated clinical reminders (3.25±0.71). Compared with traditional lab results ELRs generally saved time (3.78±0.67), reduce the need to search for information (3.67±0.71) and improve quality of care (3.78±0.67). Physicians asked whether they would prefer to use ELRs instead of traditional reports (3.78±0.67).	Moderate
Codagnone and Lupiañez-Villanueva, 2013[94]	Substantial increases in HIE use between 2007 and 2013. Qualitative results on barriers to adoption and use. Countries with National Health Systems have high HIE use that countries with social insurance or transition systems. Barriers to implementation included lack of interoperability, issues with system resilience, and security concerns. Systems that focused on administrative rather than clinical applications were used less.	Low
Dixon, Miller, and Overhage, 2013[141]	**Barriers (small hospitals, small physician practices, large physician practices)** Cost: 100%, 50%, 55% Lack of sufficient technical or human resources: 42%, 45%, 36% Lack of awareness regarding value proposition: 33%, 15%, 36%	Moderate
Dixon, Jones, and Grannis, 2013[83]	-72% in organizations with EHR; 20% involved in implementation of EHR; 10% engaged in HIE; 49% unaware of organizational involvement in HIE -<5% reporting via secure email, web-based entry, through EHR, or through HIE each	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Dixon, McGowan, and Grannis, 2011[42]	Retrospective cohort	To determine completeness and quality of data for public health electronic laboratory reporting in an HIE	Indiana	Public health	**Log file** -7.5 lab results reported in HIE -Statutory public health reporting records	November 14, 2010-December 15, 2010
Dobalian, *et al.,* 2012[142]	Cross-sectional	Describe lessons learned from one Nationwide Health Information Network implementation	Long Beach, California	3 hospitals, 2 ambulatory practice groups	**Interviews** Test data	2008
Dullabh and Hovey, 2013[158]	Multiple case studies	1) Assess the experience of states in establishing governance structures, technical services to enable health information exchange, and privacy and security frameworks; 2) Assess stakeholder priorities, current use, and anticipated need for information exchange; 3) Identify common enablers, barriers, and challenges; and 4) Collect and characterize lessons learned.	Maine, Nebraska, Texas, Washington, Wisconsin	Health Systems, provider association, state health IT coordinators, state public health agencies	**Site visits, interviews, focus groups** Not clearly stated but suggests: lab exchange, e-prescribing and exchanging clinical care documents.	November 29, 2011 - March 21, 2012
Fairbrother, *et al.,* 2014[143]	Cross-sectional	Describe the Beacon community program experience	Greater Cincinnati area, Ohio	Primary care, hospitals, federally qualified health centers and community centers insurance partners	**Interviews** Alerts for diabetic and pediatric asthma patients in ED or admitted sent to primary care.	Fall 2012

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Dixon, McGowan, and Grannis, 2011[42]	Indiana HIE (IHIE)- includes lab reports	Reporting of all lab data	NR, but in 1990s	All patients having lab tests
Dobalian, *et al.,* 2012[142]	One site in Nationwide Health Information Network, another used First Gateways exchange (HealthView). This specific HIE was called Long Beach Network for Health	Make inpatient and outpatient data available to ED. Were not yet able to exchange data about patient care.	2008	ED patients
Dullabh and Hovey, 2013[158]	Not described per state	States had two models of HIE: "thin layer" model with services based on light infrastructure (Texas, Washington and Wisconsin), or a heavy infrastructure model (Nebraska and Maine) with features such as a central repository"	NR	NR
Fairbrother, *et al.,* 2014[143]	87 primary care, 18 hospital, 7 federally qualified health centers and community centers, 3 insurance partners	Data exchange, registries, alerts to PC practices when patient in ED or admitted to hospital.	September 1, 2010 - March 31, 2013	Adult diabetics, pediatric asthma patients

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Dixon, McGowan, and Grannis, 2011[42]	7.6 million lab reports from 168 hospitals and lab information systems, of which 16,365 from 49 hospitals and lab information systems were enhanced by a Notifiable Condition Reporter	All laboratory values	NA	Proportion of fields in lab reports that were complete
Dobalian, *et al.,* 2012[142]	N=18 to sample	NR	NR	Participants in LBNH vs. not in LBNH
Dullabh and Hovey, 2013[158]	N=105 to sample; no response rate reported.	NR	NR	Comparison of 5 states
Fairbrother, *et al.,* 2014[143]	N=38 interviews to sample	Adult diabetics, pediatric asthma patients	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Dixon, McGowan, and Grannis, 2011[42]	Comparison of completeness of lab test results for regular and enhanced systems	19 data elements	NA	**Quantitative** Completeness of data fields
Dobalian, *et al.,* 2012[142]	Descriptive narrative only	NA	NA	**Qualitative**
Dullabh and Hovey, 2013[158]	Descriptive narrative only	NA	NA	**Qualitative**
Fairbrother, *et al.,* 2014[143]	Descriptive narrative only	NA	NA	**Qualitative**

Author, Year	Results	Risk of Bias
Dixon, McGowan, and Grannis, 2011[42]	-Patient identifiers and test, name, and results were nearly 100% complete for both; most but not all measures more complete for enhanced system -15 of 18 record fields showed improved completeness with enhanced system. Units of measure, normal range and abnormal flag fields all showed reduced completeness with enhanced system. No tests of statistical significance performed.	Low
Dobalian, *et al.,* 2012[142]	"Despite a limited concentration on ED care, virtually all respondents noted concerns regarding the sustainability, or business case, for the exchange of health information."	NA
Dullabh and Hovey, 2013[158]	"Results show the last 2 years have seen unprecedented growth in HIE infrastructure. Key factors such as maturity of HIE at baseline and healthcare market characteristics have shaped governance models and technical infrastructures." "Given the significant concerns about sustainability and who will pay for state-offered services in the long term, it may also prove beneficial to ensure that states have assistance, either from state or national informational resources, in developing both sustainability plans and contingency plans."	NA
Fairbrother, *et al.,* 2014[143]	Despite some setbacks and delays, the basic technology infrastructure was built, the alert system was implemented, 19 practices focusing on diabetes improvement were recognized as patient-centered medical homes, and many participants agreed that the program had helped transform care.	High

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Feldman and Horan, 2011[43]	Retrospective cohort	To determine challenges and successes of HIE for Social Security disability determination	Virginia	SSA, MedVirginia HIE, and Bon Secours Health System	**Database, interviews, audit logs** Semi-structured interviews of 43 individuals from the 3 participating organizations	June-November 2009
Dullabh, 2014[159]	Multiple Case Studies	To understand the effects of the State HIE Program on HIE progress	Six US States Iowa, Mississippi, New Hampshire, Utah, Vermont and Wyoming	Multiple	Site visits, interviews, meetings	2012-2014
Feldman, Schooley, and Bhavsar, 2014[144]	Cross-sectional	Obtain insights into technical, organizational, and governance issues of a large private health system participating in a state HIE	Virginia	Integrated delivery system	**Interviews, observations, documents** Direct observation, informal information gathering, document analysis, and semi-structured interviews	August 2012-June 2013
Finnell and Overhage, 2010[133]	Cross-sectional	To describe the underlying technology, the utilization statistics, and the survey results from the medics who used an integrated emergency medical service point-of-care system and RHIE system	Indianapolis, Indiana	EMS providers using tablets	**Survey, database**	July 1, 2009-December 31, 2009

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Feldman and Horan, 2011[43]	Medical Evidence Gathering Through Health IT (MEGAHIT)	Data for Social Security disability determination transmitted from health system through HIE to SSA via NHIN, push of background, lab, and medication data in a CCD from health system to SSA	February 2008	Patients being evaluated for Social Security disability determination; interviewed included personnel from the 3 participating organizations
Dullabh, 2014[159]	Multiple	Most projects enabled both directed and query-based HIE. While services varied they included care summary exchange, lab results, public health reporting, and transmission of admission/discharge/transfer messages.	Varies	State HIE programs supported by the Office of the National Coordinator (U.S. Federal Government).
Feldman, Schooley, and Bhavsar, 2014[144]	ConnectVirginia EXCHANGE	Query of Continuity of Care Documents	August 2012	All patients in Invoa IDS
Finnell and Overhage, 2010[133]	30 hospitals, 5 health systems, Marian County Health Department and various physician practices.	EMS providers use a button that links to the Indiana Network for Patient Care (INPC). Data are stored in a secured, password protected, centralized database. Medics receive a data abstract (pdf) of patient demographics, lab, ED, inpatient, chief complaint, coded diagnoses and procedures.	Started in 1994	Number of patients who were seen by EMS.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Feldman and Horan, 2011[43]	203	Members of 3 organizations	NA	None
Dullabh, 2014[159]	Programs In 6 states	States not included in prior rounds of case studies. States were selected for variation in program factors, state contextual factors, state HIE progress,	States included in prior case studies of this program	Programs were compared across states in terms of leadership models and other characteristics.
Feldman, Schooley, and Bhavsar, 2014[144]	10 individuals from IDS, HIE, and vendors	Members of all organizations	None	None
Finnell and Overhage, 2010[133]	26,754 patient contacts by medics. Also survey of 58 medics on use of INPC	Invited all 180 medics. 58/180 responded	NR	Comparison of use over time of study.

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Feldman and Horan, 2011[43]	Technical, organizational, and governance attributes	Mean Social Security disability case processing time 59 days (vs. average of 84)	NA	**Quantitative, Mixed Methods** Development of Collaborative Enactment Model
Dullabh, 2014[159]	Provider participation Critical mass of data exchange	Technical model Leadership model Variety and type of stakeholders	NA	Qualitative
Feldman, Schooley, and Bhavsar, 2014[144]	Technical, organizational, and governmental attributes	NA	NA	**Qualitative** Themes extracted from data
Finnell and Overhage, 2010[133]	Number of unique medic users over 6 months, number of INPC requests.	HIE use, barriers to use	NR	**Quantitative** Multivariable analysis

Author, Year	Results	Risk of Bias
Feldman and Horan, 2011[43]	-Technical challenges of HIE can be overcome but organizational and governance factors are also important 30% decrease in mean case processing time from 84 to 59 days from the usual method to HIE supported method, respectively.	Moderate
Dullabh, 2014[159]	Local stakeholder needs in the long and short term influenced decisions Other factors were cost, privacy and security Tangible intermediate goals supported implementation. Providing value and meeting Stage 2 meaningful use criteria were related to estimates of sustainability. Most programs were planning to use subscription fees for long term financial support.	NA
Feldman, Schooley, and Bhavsar, 2014[144]	Some technical challenges required workarounds, leadership and adequate resources essential, and appropriate decision making authority required	NA
Finnell and Overhage, 2010[133]	Over a six month study period, requests for patient data via HIE increased from 15% to 26% per patient contact. The majority of medics surveyed felt the HIE information was an important for delivering quality patient care.	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Foldy, 2007[84]	Cross-sectional	Description of projects, stages, users, organizational home, governance, scope, standards, drivers, challenges, recommendations	Wisconsin	Any	**Survey** Unable to access due to broken URL link	2006
Fontaine, *et al.,* 2010[85]	Cross-sectional	Examine factors that motivate or prevent small primary care practices from participating in EHR and HIE use as mandated by Minnesota e-Health Law from 2007	Minnesota	Primary care practices with <20 providers in 1 of the 3 described HIE regions	**Survey and Interviews**	November 10, 2008-February 20, 2009
Frisse, *et al.,* 2012[44]	Retrospective cohort	To examine the financial impact of HIE in EDs	Memphis, Tennessee	ED	**Log file** Tennessee Hospital Association billing database of all ED visit records	January 2007-December 2008

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Foldy, 2007[84]	NA	HIE defined as projects in which multiple independent organizations routinely send or receive electronic clinical information about patients for purposes other than billing or claims payment	NA	eHealth board, staff, consultants, workgroup members and survey respondents all nominated the survey recipients
Fontaine, *et al.,* 2010[85]	Various HIEs	9 primary care practices in Minnesota 3 HIE initiatives in Minnesota 1) a 10 year old HIO that promotes HIE and coordinates immunization registry, 2) network of independent metropolitan community clinics that received MN e-health grant funding to implement EHRs, 3) initiative to develop PHR with congestive heart failure patients	NR	39 participants in discussions
Frisse, *et al.,* 2012[44]	MidSouth e-Health Alliance (MSeHA)	11 of 12 hospitals accessed information through a dedicated secure web portal. 1 hospital printed encounter summaries as part of triage for the first 10 months of the study. Patient demographic, diagnosis, all hospital radiologic and laboratory reports, most procedure reports, and discharge summaries are exchanged.	2005	All ED visits

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Foldy, 2007[84]	30 Organizations contacted, 27 (90%) responded	eHealth board, staff, consultants, workgroup members and survey respondents all nominated the survey recipients	NR	NA
Fontaine, *et al.*, 2010[85]	Unclear	NA	NA	NA
Frisse, *et al.*, 2012[44]	15,798 visits in which HIE was accessed; matched comparison group of 15,798 cases	ED visit to 1 of the participating hospitals. Visit only in HIE or no HIE subset.	Patients in both the HIE and no HIE subset (932) HIE accessed in non ED setting (3,555)	Encounters with vs. without HIE

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Foldy, 2007[84]	-Status of projects operation vs. planned -Stage of development -Description of information users -Organization, funding, governance -Scope -Standards -Drivers -Challenges -Recommendations	NA	NA	**Quantitative** Descriptive Stats
Fontaine, *et al.,* 2010[85]	-Use of EHR -What data elements are being sent/received	NA	NA	**Qualitative** Descriptive statistics
Frisse, *et al.,* 2012[44]	-Financial consequences based on ED-originated hospital admissions -Admissions for observation, lab tests, head or body CT, ankle or chest radiographs, echocardiograms	HIE accessed during ED visit	-Admission type -Length of stay -Charlson comorbidity index -Patients matched on age, gender, race, site of ED, diagnosis and payer	**Quantitative Multivariate Analysis** Generalized estimating equation logistic regression

Author, Year	Results	Risk of Bias
Foldy, 2007[84]	-27 responded, 21 judged to be HIE organizations, 21 respondents had 16 operational projects, 11 planned projects -Rating of most advanced HIE project had 40% of respondents in implementation and 40% in operational -44% deliver data only to central registries, 50% deliver to providers and registries and only 1 to providers only -62.5% are based in government organizations -73% started with only public funds, 20% exclusively private, 75 used both -For continued operations 57% rely entirely on public funds, 21% only on private and 21% a combo -Governance all have multiple stakeholders -14 are statewide, 7 southeast Wisconsin, 2 south, central and north and west. -Standards 46% of projects have specific vocabulary or data standards	Moderate
Fontaine, *et al.,* 2010[85]	-8/9 practices uses EHR -Only 1 practice was able to transmit/receive patient health records -All 9 practices shared information with department of health immunization registry though not through any of the EHRs in the practices -Labs were next most common Several practices were receiving data directly into EHRs -None were sharing data with nonaffiliated practices -HIE motivations themes: External - government mandates, payer mandates, quality reporting; Internal - cost savings, quality/patient safety, efficiency -HIE barriers: lack of interoperability, lack of buy-in, competition, security, costs, creating business model, limited success and large time investment, limited technical support -No practice was fully involved in a regional HIE; HIE was not part of most practices' short-term strategic plans.	Moderate
Frisse, *et al.,* 2012[44]	HIE accessed: 6.8% of ED visits (in 12 EDs) **Admissions when HIE used** Adjusted OR 0.27; 95% CI, 0.210 to 0.351, p<0.0001 191 fewer admissions with HIE vs. without HIE -In 11 EDs directly accessing HIE data only through a secure Web browser, access was associated with a decrease in hospital admissions (adjusted OR 0.27; p<0001) -In 12th ED relying on print summaries, HIE access was associated with a decrease in hospital admissions (OR 0.48; p<0001) and statistically significant decreases in head CT use, body CT use, and laboratory test ordering -HIE access associated with annual cost savings of $1.9 million, with hospital admission reductions accounting for 97.6% of total cost reductions	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Furukawa, *et al.,* 2013[111]	Time Series	Describe extent of HIE in U.S. hospitals	All 50 states and the District of Columbia	Hospital	**Survey** Health IT supplements to the American Hospital Association Annual survey of hospitals, 2008-2012. 63% response rates. 2,805 hospitals in 2008, 2,836 hospitals in 2012. nonfederal acute care hospitals	2008-2012
Furukawa, *et al.,* 2014[110]	Cross-sectional	NAMCS Survey, How have rates of EHR changed since HITECH? What % of MDs are engaged in HIE in 2013? What % are using PHR in 2013? How did these things vary by physician and practice characteristics?	U.S.	U.S. ambulatory providers	**Surveys**	2009-2013
Gadd, *et al.,* 2011[86]	Cross-sectional	To assess the usability of an HIE in a densely populated metropolitan region	3 counties around Memphis, Tennessee	ED and outpatient clinics	**Survey** Email survey responses from 165/ 237 health care professionals (70% response rate)	June-November 2009
Genes, *et al.,* 2011[145]	Cross-sectional	What are perceptions of ED users of HIE?	New York City	ED	**Interviews** Semi-structured interviews of users and nonusers	NR

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Furukawa, *et al.,* 2013[111]	NA	NA	NA	U.S. acute care nonfederal hospitals
Furukawa, *et al.,* 2014[110]	NA	NA	NA	Ambulatory physicians not radiologists, pathology, or anesthesia
Gadd, *et al.,* 2011[86]	MidSouth e-Health Alliance (MSeHA) A rapid deployment HIE that consolidated data from several sources	Consolidated data from multiple hospital EDs and community-based ambulatory clinics. Decentralized, query-based exchange. Consent was opt-out.	2004 in 3 counties	Medical staff (Physicians, Nurse Practitioners, Physicians assistants, nurses, and other) at organizations participating in the HIE
Genes, *et al.,* 2011[145]	New York Clinical Information Exchange (NYCLIX)	All data from 10 academic medical centers	2009	ED physicians

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Furukawa, *et al.*, 2013[111]	2,805 hospitals in 2008 and 2,836 in 2012 Various HIEs	NA	NA	NA
Furukawa, *et al.*, 2014[110]	NR	NA	NA	NA
Gadd, *et al.*, 2011[86]	162 responses analyzed Details on sample: 345 people identified; 269 valid contacts; 237 surveys distributed; 165 responses (69.6%); 3 excluded for missing responses on satisfaction items.	NR other than list of roles included	People who were no longer employed by the system were not contacted	The impact of usability on use of HIE
Genes, *et al.*, 2011[145]	18 users of NYCLIX ED pilot	All users	NA	-For users, was HIE data useful? -For nonusers, why not using?

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Furukawa, *et al.*, 2013[111]	Any exchange activity with outside providers outside the organizations	NA	-Provider type -Organizational affiliation -Type of clinical information -Hospital characteristics -Area characteristics	**Qualitative** Descriptive statistics
Furukawa, *et al.*, 2014[110]	Descriptive statistics	NA	NA	**Quantitative** Descriptive statistics and logistic regression
Gadd, *et al.*, 2011[86]	-Use -Questionnaire for User Interaction Satisfaction (QUIS 7.0) -Trust	None	None	**Quantitative, multivariable analysis** -Wilcoxon rank sum test -Descriptive statistics -Ordinal logistic regression
Genes, *et al.*, 2011[145]	-For users, was HIE data useful? -For nonusers, why not using?	Semi-structured interviews	None	**Qualitative**

Author, Year	Results	Risk of Bias
Furukawa, *et al.,* 2013[111]	-58% of hospitals exchanging in 2012, 41% increase of 2008, p<0.01 -2012 51% hospitals exchanged with unaffiliated ambulatory providers, 36% with other hospitals outside their organization -2012 52%, 53%, 35% and 33% exchanging radiology reports, labs, care summaries and prescription lists with outside providers, respectively. That is a 39%, 51%, 40%, 55% increase, respectively. -After adjusting for hospital and area characteristics hospitals with basic EHR and participation in Health information organizations 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% of hospitals with EHR but no HIO were exchanging, all consistent across different providers types and clinical information types -Hospital characteristics associated with lower exchange rates, rural, for-profit, locations with greater Medicare part A spending	Low
Furukawa, *et al.,* 2014[110]	-Broad HIE definition (39% of office-based physicians reported having an HIE with other providers or hospitals). Increased odds of HIE both within and outside of their organization with larger practice, health-system owned practice and multispecialty practice. Very few characteristics associated with HIE outside of the practice, significantly lower outside HIE with community health centers and practice outside of metropolitan statistical centers -35 % HIE inside, and 13% HIE outside	Low
Gadd, *et al.,* 2011[86]	151 users (93%), 11 non users **Average usage per week** <1 hour: 65 (43%) 1 hour to <4 hours: 58 (39%) ≥4 hours: 27 (18%) Mean usability scale: 6.5 SD 1.4 (>5 is favorable, out of 9) **Association of Scales with higher use (ORs)** Overall reactions: 1.50, p<0.01 Learning: 1.32, p<0.05 System functionality: 1.34, p<0.01 Trust not predictive of usage. Users commented that HIE needs more tech support and could use more types of data	Low
Genes, *et al.,* 2011[145]	-Half of users reported usage affecting patient care on ≥1 occasion -nonusers reporting forgotten login credentials	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Goldwater, *et al.,* 2014[146]	Cross-sectional	Evaluate the progress of the HIE, how many providers and hospitals were participating in the program, and what benefits were being realized through the use of the HIE.	Washington, District of Columbia	6 acute care hospitals	**Interviews, focus groups, survey** Demographic, inpatient, encounter notifications, lab testing, electronic prescribing services, integration with public health and Medicaid providers.	July 1, 2013-January 6, 2014. Survey of 148 individuals and stakeholders released October 1, 2013 and closed November 4, 2013.
Greenhalgh, *et al.,* 2010[121]	Mixed-method; multi-level case study of England's Summary Care Record (SCR)	1) What is usability, use, functionality, and impact of SCR; 2) What explains variation in its adoption and use; 3) How has the programme been constrained by influences at the macro, meso, micro level; 4) What are the transferable lessons for practice and policy?	3 districts within the English National Health Service	ED and unscheduled care	**Qualitative data:** 140 interviews of policy makers, managers, clinicians, software suppliers; 2,000 pages of ethnographic field notes; Observation of 214 clinical consultations; 3,000 pages of documents. **Quantitative Data:** 416,325 encounters in 3 participating clinics	2009-2010? Not quite clear
Grossman, Kushner, and November, 2008[160]	Multiple case studies	Compare differences in success and barriers for HIEs	Indiana, Cincinnati, Northeast Tennessee, Tampa Bay	Any	**Interviews of stakeholders**	February-August 2007

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Goldwater, *et al.,* 2014[146]	The 6 acute care hospitals chose the Chesapeake Regional Information System for our Patients	Demographic, inpatient, encounter notifications, lab testing, electronic prescribing services, Integration with public health and Medicaid providers.	Launched February 2012	Survey sent to 148, 30 completed 20% response rate
Greenhalgh, *et al.,* 2010[121]	SCR, which was comprised of 3 data fields - medications, allergies and adverse reactions	Not specified	2007-2010	2007-two early adopter clinics; 2010 - 113 of 152 primary care trusts in England had committed to participating; by 2010, 16 had begun to create SCRs; By 2010, 1.5 million records had been created.
Grossman, Kushner, and November, 2008[160]	IHIE, HealthBridge, CareSpark, Tampa Bay RHIO	All types	Varying	Stakeholders in 4 HIEs

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Goldwater, *et al.*, 2014[146]	NR	NR	NR	NA
Greenhalgh, *et al.*, 2010[121]	1.5 million records in 2010	3 districts who were implementing SCRs	Not specified	None
Grossman, Kushner, and November, 2008[160]	2 mature and 2 newer	NA	None	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Goldwater, *et al.,* 2014[146]	Descriptive narrative only	NA	NA	**Mixed Methods**
Greenhalgh, *et al.,* 2010[121]	What is usability, use, functionality and impact of the SCR; What explains variation in adoption and use; How does context play in; What are the lessons to practice and policy	None	None	**Qualitative** Interpreted and themed **Quantitative** Descriptive statistics and logistic regression
Grossman, Kushner, and November, 2008[160]	Success, barriers, sustainability	NA	NA	**Qualitative**

Author, Year	Results	Risk of Bias
Goldwater, *et al.,* 2014[146]	"HIE is used to electronically capture and report immunization data; and in requiring electronic lab reporting and results as part of the Meaningful Use Requirement—which can assist in detecting HIV/AIDS and providing better care for the district's high population of individuals with HIV/AIDS. Electronic lab reporting and electronic prescribing within the HIE can assist the Department of Health and providers in identifying specific diseases, such as tuberculosis and viral hepatitis, before they affect a significant part of the population. '	Moderate
Greenhalgh, *et al.,* 2010[121]	Adoption was complex, technically challenging, labour intensive; Went more slowly than planned; SCR accessed in 4% of all encounters; SCR accessed in 21% of encounters where an SCR was available; Main determinant of success was clinician characteristics (which were not specified); When available, clinicians accessed SCR 0% to 84% of time; SCR supported better quality care and increased clinician confidence; No direct evidence of improved safety; SCR not associated with shorter clinical consultations; Successful implementation hinged on successful interactions among multiple stakeholders (clinical, technical, political)	Low
Grossman, Kushner, and November, 2008[160]	Stakeholder buy-in essential for success, offering hospitals value to reduce costs important, hospitals concerned about controlling access to data, employers and health plans not buying in	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Gutteridge, *et al.,* 2014[112]	Cross-sectional	To describe the development and use of a CEN system based on an HIE.	New York metropolitan are	ED, hospital, and outpatient	**Subscription lists and reports generated**	March 11, 2013-March 2, 2014
Hamann and Bezboruah, 2013[113]	Secondary analysis of cross-sectional survey	To examine ownership differences (for-profit; nonprofit) in the use of technology in long term care facilities	U.S.	Nursing homes and residential care	**Surveys** 2004 National Nursing Home Survey; 2010 National Survey of Residential Care Facilities	Nursing home: August 2004-January 2005 Residential care: 2010
Herwehe, *et al.,* 2012[124]	Cross-sectional	To conduct a formative evaluation of an HIE for HIV that integrates public health and clinical information	Louisiana	Health department, hospital, outpatient	**Interviews, focus groups, log data**	February 1, 2009 and January 31, 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Gutteridge, *et al.,* 2014[112]	Healthix	A federated architecture for data sharing. Log in is via a standalone web portal -Healthix included a total of 107 organizations with 383 facilities, 9.2 million patients, and >6,500 users performing >10,000 patient searches per month as of January 2014	2004 was initial funding CEN system March 2013	Geriatric patients seen in ED and admitted to hospitals
Hamann and Bezboruah, 2013[113]	Varies, NR	Varies, NR	Varies	Long term care Facilities Nursing home is U.S. Residential Care (aka Assisted Living in U.S.)
Herwehe, *et al.,* 2012[124]	The Louisiana Public Health Information Exchange (LaPHIE)	A secure bi-directional public health informatics application (an HIE in a broad sense, as defined by Dixon et al.), linking statewide public health surveillance data with patient-level EMR data.	Started February 2009 and in all participating hospitals by September 2009	Patients with HIV seen for non HIV services at 7 Louisiana Hospitals; 442 clinicians (206 physicians and 236 nurses) trained on system to serve as peer trainers

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Gutteridge, *et al.,* 2014[112]	These patient who are enrolled in the system	NA	NA	None
Hamann and Bezboruah, 2013[113]	Nursing home Sample: 1,174 response rate 81% Residential care Sample: 2,302 response rate 81% Various HIEs	NR	NR	Nonprofit vs. for profit use of health IT including HIE
Herwehe, *et al.,* 2012[124]	16 focus groups n=149; and 23 key informant interviews with patients	NA	NA	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Gutteridge, *et al.*, 2014[112]	-Enrollment of patients -Number of notifications sent	NA	NA	**Counts**
Hamann and Bezboruah, 2013[113]	Whether facility shares information electronically with other care partners and the extent of HIE defined as the number of entities with which the facility shares information	Nonprofit or for-profit ownership	-Chain ownership -Size of facility and type of residents -Use of volunteers -% revenue from Medicaid and Medicare	**Quantitative** -Chi^2 -Ordered Logit regression
Herwehe, *et al.*, 2012[124]	Patients identified and matched providers responses to alerts	NA	NA	**Mixed methods** -Description -Counts of alerts and responses

Author, Year	Results	Risk of Bias
Gutteridge, *et al.,* 2014[112]	-5,722 patients enrolled (612 notifications sent) -Without duplications 497 event notifications about 206 unique patients -Notifications originated from 23 separate institutions, ED visits comprised 44% (219 of the 497 notifications), 98 notifications were for inpatient admissions -121 of 497 (55%) during normal business hours -Hospital admissions resulted from 45% of ED visits; 17.8% of these lasted <48 hours, suggesting they were avoidable -70% of notifications were received within 1 hour of the event, during the study year; in following year 71% were received within 15 minutes	NA
Hamann and Bezboruah, 2013[113]	**For Profit/Nonprofit (corrected F)** % Residential care using HIE: 0.14/0.21 (10.29), p=0.00 Number of partners in HIE: 0.32/0.42 (2.56), p=0.02 **Regression results:** for profits less likely to participate in HIE OR 0.663, p<0.001 Supports hypothesis and proposed framework for why nonprofits are more likely to use health IT NOTE: NH survey did not have HIE question	Low
Herwehe, *et al.,* 2012[124]	**In the 2 year period 2/1/2009 to 1/31/2011:** -488 registrations of patient (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 healthcare 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	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Hessler, *et al.,* 2009[87]	Cross-sectional	To understand assessment of HIE by RHIO and state and local public health department representatives	U.S.	RHIOs and State and Local Health Departments	**Survey** Online survey created by researchers	late February 2007-March 25, 2007
Hincapie, *et al.,* 2011[132]	Cross-sectional	Assess perceptions of physicians users of HIE	Arizona	All physician use	Focus group meetings of 29 physicians on HIE quality of care, workflow and cost	NR
Hyppönen, *et al.,* 2014[133]	Cross-sectional	To compare usability of different regional health information exchange system (RHIE) types as well as the factors related to the experienced level of success	Finland	Varies as this includes sites with RHIE	Survey	2010
Jha, *et al.,* 2008[117]	Cross-sectional, mixed modes	To assess health IT, including HIE adoption in 7 countries	U.S., U.K., Canada, Germany, Netherlands, Australia, New Zealand	Physicians and hospitals	Literature review, available surveys, (Medline and Google) and interviews with governmental and nongovernmental experts	Literature review: 2000 -2006

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Hessler, *et al.*, 2009[87]	Varies, NR	Varies, NR	Varies	164 RHIOs 540 health agencies
Hincapie, *et al.*, 2011[132]	Arizona Medical Information Exchange (AMIE)	Medication history, lab test results, and discharge summaries	October 2008	Physicians who agreed to participate in focus groups
Hyppönen, *et al.*, 2014[133]	Regional Health Information Exchange	Varies depending on type of RHIE system. Type 1: master patient index required separate login to centralized database. Type 2: web distribution model. Limited group of referring physicians could see hospital info. Type 3: regional virtual model. If patient grants permission, clinician uses integrated system that includes all inpatient and outpatient information.	Before 2010	Inpatients and outpatients of physicians working in public sector in 13 regions of Finland where RHIE systems were in use.
Jha, *et al.*, 2008[117]	Varies, NR	Varies, NR	Varies	Developed countries

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Hessler, *et al.*, 2009[87]	N=44 RHIOs (27% response); 20 non-governmental N=138 Health agencies (26% response); 41 state and 97 local public health agencies	RHIOs: listed in 1 of 7 sources Public Health: on list from national associations	Missing or invalid email addresses or an exchange specific to 1 disease	RHIOs vs. state vs. local health officials
Hincapie, *et al.*, 2011[132]	29 physicians	Physicians who agreed to use system and participate in focus groups	None	None
Hyppönen, *et al.*, 2014[133]	1,693 physician respondents aged less than 65 years. 1,079 specialize care; 614 primary care	Physicians working in public sector in 13 regions of Finland where RHIE systems were in use.	Physicians in the private sector or in regions where RHIE not in use whole region or was unavailable	Comparison of HIE usability by type of RHIE and EHR
Jha, *et al.*, 2008[117]	7 selected for data availability	NA	NA	HIE use across countries

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Hessler, *et al.*, 2009[87]	-Sharing of data -Challenges -Unique resources -Minimal requirements	Type of respondent	Characteristic reported but not used in analysis	**Mixed Methods** -Descriptive statistics, no significance tests -Qualitative assessment of open-ended responses
Hincapie, *et al.*, 2011[132]	Benefits and disadvantages of HIE	Transcripts	NA	**Qualitative** Thematic analysis from transcripts
Hyppönen, *et al.*, 2014[133]	Levels of agreement to 11 statements about HIE success	RHIE type used, local EHR system used, working sector and primary means of HIE	Managed multi-collinearity	**Quantitative, multivariable analysis** Models to predict successful HIE, stratified by type of clinician user (specialized or primary care). Results were broken out by function of HIE.
Jha, *et al.*, 2008[117]	-HIE existence -Use -Policies promoting development	Country	NR	**Descriptive, qualitative**

Author, Year	Results	Risk of Bias
Hessler, *et al.,* 2009[87]	Public Health: 50 (36%) no RHIO in jurisdiction; 16 (12%) no relationship with RHIO; 26 (40% responding to item) are exchanging information RHIOs: 12 (60%) are exchanging info; 7 (35% with public health); lab data shared most frequently (86% of the time) **Challenges (RHIO/Local/State % endorsing)** Lack of standards: 33/12/15 Limited resources: 17/67/45 **Unique resources Public Health brings** Perspective: 41/45/30 Data: 35/16/39 **Minimum Public Health must bring** Commitment: 50/31/23 Funding/sweat equity: 33/43/47 More dialogue about needs and expectations could increase HIE; early successes with lab data could encourage future use.	High
Hincapie, *et al.,* 2011[132]	Benefits included identification of "doctor shopping", avoiding duplicate testing, and increased efficacy for gathering information; disadvantage was limited availability of data	Moderate
Hyppönen, *et al.,* 2014[133]	Users of three local EHR systems preferred electronic HIE to paper to a larger extend than users of other EHR systems. Experiences with an integrated RHIE system (type 3) were more positive than those with other types or RHIE systems.	Low
Jha, *et al.,* 2008[117]	**Australia:** early pilots, but no major investment. Lack of unified patient identification 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 admin data now **The Netherlands:** National SwithPoint pilot with 20% of population, plan full implementation in 2008 **New Zealand:** planning stage, have unified patient Id, focus of discharge, lab and path reports to GPs **U.K.:** National Program, 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	High

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Johnson, *et al.,* 2008[99]	Multiple site case studies	To assess first year of MidSouth eHealth Alliance	Memphis, Tennessee	EDs	**Audit logs, database (administrative), comments by users**	Implied 1 year after May 2006; but data on use in January 2008
Johnson, *et al.,* 2011[118]	Multiple site case studies	To explore characteristics of use and uses of a regional HIE	Memphis, Tennessee	EDs, ambulatory groups	**Audit logs, database administrative data, observations, comment cards, feedback in system, interviews, observations**	Interviews 1 month, 1 year after system in use in all sites Audit data and ED visits January 2008-June 2008
Jones, Friedberg, and Schneider, *et al.,* 2011[68]	Cross-sectional	To evaluate the association between hospitals' HIE and health IT use and 30-day risk adjusted readmission	U.S.	Hospitals	**Database** 2007 AHA Survey 2009 September Hospital Compare	June 2005-June 2008 for Hospital Compare
Kaelber, *et al.,* 2013[120]	Cross-sectional	What is use and perceived value of HIE?	Northeast Ohio	Public healthcare system	**Usage logs, survey of users**	November 2010-December 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Johnson, *et al.*, 2008[99]	MidSouth eHealth Alliance (MSeHA)	Multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Data Exchanged: demographics, ICD-9 discharge codes, lab results, encounter data, and dictated reports. These are in a vault controlled by the hospital, but accessed when a query is made, unless patient opts out.	May 2006	ED staff in 5 participating sites
Johnson, *et al.*, 2011[118]	MidSouth eHealth Alliance (MSeHA)	Data Exchanged: demographics, ICD-9 discharge codes, lab results, encounter data, and dictated reports. Multiple hospital emergency departments and community-based ambulatory clinics. Decentralized. These are in a vault controlled by the hospital, but accessed when a query is made, unless patient opts out.	May 2006 in EDs later in clinics (NR)	6 ED sites and 9 clinics for interviews All visits records and usage logs
Jones, Friedberg, and Schneider, *et al.*, 2011[68]	Varied. As defined by hospital	Varied. As defined by hospital	Varied. As defined by hospital	Hospitals in U.S.
Kaelber, *et al.*, 2013[120]	HIE in Northeast Ohio	10 hospitals and affiliated practices using Care Everywhere	November 2010	Not stated for patient population, 412 physician users

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Johnson, *et al.*, 2008[99]	5 sites; number of users varies by site	NR	NR	HIE use across sites and overall
Johnson, *et al.*, 2011[118]	Number of people interviewed NR 369 comments (12% of all visits)	NA	NA	NA
Jones, Friedberg, and Schneider, *et al.*, 2011[68]	2,406 hospitals (58% of eligible hospitals responded to AHA survey)	General acute care non federally owned U.S. hospitals	Not specified. Specialty and federal implied by inclusion criteria	Hospitals that self report exchanging any information with ambulatory providers outside their system vs., hospitals who say they do not participate in this type of HIE
Kaelber, *et al.*, 2013[120]	74 (18%) of physicians who replied to survey	All users	NA	-Measurement of usage -Perceptions of users

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Johnson, *et al.,* 2008[99]	-% of ED visits with HIE use -% of users who logged in -Theme from comments: perception that HIE reduces redundant testing was most common	NA	Role (Nurse, MD, registrar, unit clerk)	**Quantitative, descriptive statistics** Counts and percentages
Johnson, *et al.,* 2011[118]	-HIE Access -Type of data accessed -Provider log on rates	NA	-Profession (Doctors or nurse/clerk) -Type of visit	**Mixed Methods** -quantitative, descriptive data -qualitative analysis -Counts and percentages
Jones, Friedberg, and Schneider, *et al.,* 2011[68]	All- cause 30-day risk-standardized readmission rates for patients initially admitted with acute myocardial infarction, heart failure, or pneumonia.	HIE Participation (also use of health IT)	Hospital characteristics (ownership, critical access status, trauma status, number of beds, teaching status, system membership, core-based statistical area type, U.S. census division, long term care unit, critical care unit)	**Quantitative** -Unadjusted mean differences -Propensity score matching -Linear regression
Kaelber, *et al.,* 2013[120]	-Measurement of usage -Perceptions of users	-Usage of HIE -Survey of users	None	**Quantitative** Descriptive and Multivariate

Author, Year	Results	Risk of Bias
Johnson, *et al.*, 2008[99]	HIE viewed in 2.6% of all visits and 9.5% of visits where patient had visit to other site in past 30 days. % 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 -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	NA
Johnson, *et al.*, 2011[118]	**HIE access** Patient encounters increased over 24 months: 4% to 6.5% (range: 1 to 16 % across sites) 14.6% for return ED visits and 18.7% for return clinic visits (p<0.001) Higher where nurses and clerks involved and lowest where MD only access Patient opt out rates: 1% to 3% Primary user reported consequence of HIE: provided additional history (29%), prevented repeat test or procedure (19.8%)	NA
Jones, Friedberg, and Schneider, *et al.*, 2011[68]	**Unadjusted readmission rates (no HIE vs. HIE)** Acute myocardial infarction: 20.0 vs. 19.8, p=0.14 Heart failure: 24.6 vs. 24.3, p=0.003 Pneumonia: 18.2 vs. 18.1, p=0.68 **Hospitals did not participate in HIE:** 58.7% **Adjusted readmission rates (no HIE vs. HIE)** Acute myocardial infarction: 19.9 vs. 19.8, p=0.18 Heart failure: 24.4 vs. 24.2, p=0.11 Pneumonia: 18.2 vs. 18.1, p=0.68	Low
Kaelber, *et al.*, 2013[120]	Usage of HIE ED: 31% to 35% Primary care: 18% to 22% Specialty care: 9% to 11% -Usage highest among patients who were older, with more comorbid 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%)	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Kaushal, *et al.,* 2010[60]	Cross-sectional	To assess users experiences with an HIE project that provided medications information to EDs.	Massachusetts	5 Massachusetts Emergency Rooms	**Survey** Semi-structured interview covering need for intervention, history, personal use, induction, current us, completeness and accuracy, value added, rollout to other hospitals and evaluation Pharmacy benefit claims data	December 2005
Kern, *et al.,* 2011[171] Same as Kern, *et al.,* 2009[173]	Prospective cohort	To determine predictors of sustainability among community-based organizations implementing health IT including HIE in a state with significant funding of such organizations.	New York	Varies (setting was part of analysis)	**Survey and administrative data** Baseline assessment and New York State Department of Health information on awarded grants	Phone Interviews January-February 2007 (same as baseline for Kern, 2009). New York State Department of Health data: March 2008
Kern, *et al.,* 2009[173]	Time series	To identify lessons for state-based initiatives that can be learned from HEAL NY	New York	NR	**Organizational assessment** Baseline and followup assessments	Baseline: January-February 2007 Followup: July-August 2008
Kern, *et al.,* 2012[45]	Retrospective cohort	To determine the effect of HIE on ambulatory quality	Hudson Valley region, New York	Physician small group practices	**Log file** From Portal for usage, MVP Health Care Quality Reports including HEDIS measures and satisfaction	January 2005-June 2006 (split into 3 6-month periods)

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Kaushal, *et al.*, 2010[60]	MedsInfo-ED, a project Massachusetts Health Data Consortium (MHDC)	Claims data from pharmacy benefit managers (PBMs) were made available at the point of care to clinicians in the EDs	2004	Staff at participating sites
Kern, *et al.*, 2011[171] Same as Kern, *et al.*, 2009[173]	Varies	NR	Varies	HEAL 1 Grantees given awarded funds for health IT
Kern, *et al.*, 2009[173]	Varies	NR	Varies	HEAL Grantees given awarded funds for health IT
Kern, *et al.*, 2012[45]	MedAllies Portal covers 2 counties, 5 hospitals, and 2 labs	Internet-based with secure log-in from any computer. Providers can view tests and results order by themselves or others.	2001	Taconic Independent Practice Association MDs

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Kaushal, *et al.,* 2010[60]	N=12 interviewed of 15 contacted	3 EDs that were pilot sites; 2 more added in expansion. Agreement to participate from MassHealth and 5 health plans.	Patients not covered by participating plans	Comparisons across the 3 initial pilot sites
Kern, *et al.,* 2011[171] Same as Kern, *et al.,* 2009[173]	26 Phase I grantees (100%)	HEAL 1 Grantee	NA	Organizations that received further funding vs. those that did not
Kern, *et al.,* 2009[173]	26 HEAL grantees	NA	NA	NA
Kern, *et al.,* 2012[45]	138 MDs with quality information (out of 168, 82%) 79 nonusers and 59 users of the HIE portal	≥150 patients with MVP Health Care	No quality of care data	Physicians who used portal vs. those who did not

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Kaushal, *et al.*, 2010[60]	Descriptive narrative only	NA	NA	**Thematic analysis** Coding of interview transcripts by tow investigators
Kern, *et al.*, 2011[171] Same as Kern, *et al.*, 2009[173]	Receipt of HEAL 5 funds	-Responses to 26 questions covering 9 areas -Type of organization that was the lead application (health care or health information)	NA	**Quantitative multivariate analysis** -Bivariate and multivariate logistic regression -Backward stepwise elimination
Kern, *et al.*, 2009[173]	-Grantee still in operation -Exchanging data or implementing other IT -Met definition of RHIO	NA	None reported	**Quantitative** -Counts and proportions -McNemar 2-sample test for binomial proportions for matched-pair data for comparison between baseline and followup
Kern, *et al.*, 2012[45]	-Rate of portal use -Quality of care	Any portal use	-Physician characteristics -Case mix	**Quantitative** -Chi^2 -t-tests -Fischer exact tests -Generalized estimating equation regression

Author, Year	Results	Risk of Bias
Kaushal, *et al.,* 2010[60]	**Need:** respondents believed gaps in medical information are an important problem and this system could help Information was perceived as accurate, range of estimate of patients with information 15% to 80% **Perception:** system improved knowledge but did not decrease time and did not improve care enough to justify hospital paying for system **Barriers:** need for patient consent, difficulty matching patients **Suggestions:** increasing the types of information included (e.g., psychiatric, HIV, and mail order medications) and improving the format of the output	High
Kern, *et al.,* 2011[171] Same as Kern, *et al.,* 2009[173]	**Predictors of funding from bivariate (OR, 95%CI)** Lead by health information organization: 11.4, 1.7 to 78.4, p=0.01 Performed community-based needs assessment: 5.1, 0.8 to 32.3, p=0.08 Targeting long term care settings: 0.14, 0.02 to 0.79, p=0.03 **Predictors of funding from multivariate (OR, 95%CI)** Lead by health information organization: 6.4, 0.8 to 52.6, p=-.08	High
Kern, *et al.,* 2009[173]	-All grantees still existed at followup -Half decreased number of planned projects (3 possible: HIE EHR, electronic prescriptions) -HIE all grantees planning at baseline, 85% at followup (22 of 26) -9 (35%) had users ranging from 5 to 1600. HIE was most common project. -13 baseline/20 followup met definition of RHIO -Expected interventions (not just HIE) to save money: 65% baseline, 35% followup p=0.02 -Concern about financial and technical barriers increased by followup	Moderate
Kern, *et al.,* 2012[45]	-% 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) -Quality score at followup: 49 for nonusers vs. 64 for users, p<0.0001 -OR for higher quality use of portal: 1.42 (95% CI, 1.04 to 1.95) -Average ambulatory quality of care for composite of 15 measures, stratified by time and use of HIE showed difference between non-users vs. users (49% vs. 64%, p<0.0001) at followup and among users between baseline vs. follow-up (57% vs. 64%, p<0.001)	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Kern, *et al.,* 2012[147]	Cross-sectional	To understand which components of EHRs and HIE are most likely to drive financial savings in the ambulatory, inpatient, and ED settings.	NA	Ambulatory, inpatient, and ED settings.	**Literature and expert consensus** Literature search results, input of 28 national experts, analysis of Stage 1 of Meaningful Use	April 2007 (expert review)
Kho, *et al.,* 2013[88]	Prospective cohort	To describe the use of an HIE for tracking patients with antimicrobial resistance	Indianapolis, Indiana	Hospital and associated clinics	**Survey, log data**	June 2007-June 2010
Kierkegaard, Kaushal, and Vest, 2014[127]	Multiple site case studies	To investigate how HIE can better meet the needs of care practitioners	3 communities (RHIOs) in New York State	ED and outpatients	**Observations, interviews** 2 day site visits, onsite and telephone interviews with HIE users and nonusers, observations of workflow	May-June 2013
Lammers, Adler-Milstein, and Kocher, 2014[69]	Cross-sectional	To evaluate whether HIE is associated with decreases in repeat imaging in EDs	California and Florida	EDs	**Database** State ED databases, Health Information Management Systems Society data, AHA annual survey	2007-2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Kern, *et al.,* 2012[147]	NA	NA	NA	HIE functions by settings
Kho, *et al.,* 2013[88]	Indiana Network for Patient Care (INPC)	5 hospital systems (17 hospitals)	May 2007 for this tracking function	Infection preventionists at all hospitals; patients with MRSA or VRE
Kierkegaard, Kaushal, and Vest, 2014[127]	NA	2 federated model, 1 centralized model. All required login to standalone web portal 2 provided automated delivery of imaging and lab results 1 included patient portal and iPhone app 1 included secure messaging and event notification. Query- based but also provided direct exchange of CCD	NR	11 RHIOs in NY and users and non users of HIE
Lammers, Adler-Milstein, and Kocher, 2014[69]	Varies, not a single HIE	Varies	Varies	ED visits in California and Florida

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Kern, *et al.*, 2012[147]	Top 10 functions based on researcher ratings	In top 10 for function based on: 1) probability of achieving a benefit, 2) time to benefit, 3) probability of measuring a benefit for initial framework. Experts added 3 additional criteria 4) complexity, 5) likelihood of usage, and 6) expected magnitude of impact	Rating below top 10	High rated functions across setting and between HIE and EHRs
Kho, *et al.*, 2013[88]	NR	NA	NA	NA
Kierkegaard, Kaushal, and Vest, 2014[127]	N= 38 interviews 3 sites (13, 15, 10) 3 EDs, 7 outpatient 3 types of respondents: MDs, other clinical users, administrative users	Received HEAL NY funding and been in existence for ≥7 years, and distinct.	NA	Themes across sites
Lammers, Adler-Milstein, and Kocher, 2014[69]	Patients at HIE adopters: 33,084 (11%) Patients at non adopters: 274,640	ED visits with data in State and HIMSS, patient had another ED visit in prior 30 days in different EDs, or selected imaging in index visit	ED visits that resulted in admissions	37 EDs that participated in HIE vs. 410 that did not

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Kern, *et al.,* 2012[147]	Rating of function	Setting type (HIE, EHRs)	NA	**Quantitative** ANOVA for scores across settings t-tests for HIE, EHRs comparisons
Kho, *et al.,* 2013[88]	-Number of alerts generated -Number of patients admitted to multiple hospitals -User satisfaction/ burden -Coordinated antibiotic-resistant infection tracking, alerting and prevention	NA	NA	**Counts**
Kierkegaard, Kaushal, and Vest, 2014[127]	Themes related to use of HIE	Site and type of setting	NA	**Qualitative** -Thematic analysis from transcripts -Dual coding of interviews -Iterative coding, grouping of themes in categories continued until saturation
Lammers, Adler-Milstein, and Kocher, 2014[69]	Repeat CT, ultrasound or chest x-ray in same body region within 30 days at unaffiliated EDs	HIE participation in each year	-Patient demographics -Number of days between ED visits -comorbidities -Total annual ED discharges -ED characteristics	**Quantitative** Regression with fixed effects and trends

Author, Year	Results	Risk of Bias
Kern, *et al.*, 2012[147]	-73 setting-HIE function pairs were identified -Mean function score (range 6 to 18): 13.0 EHR vs. 11.3 HIE, p<0.0001 -No difference in scores across setting (p=0.33) -High scoring HIE functions: transferring imaging reports (all settings), receiving lab results (outpatient and ED), enabling structured medication reconciliation -HIE functions were considered more difficult to implement (complexity and time) vs. EHRs -HIE is most likely to generate a positive financial effect through its ability to coordinate care among providers. Based on assessment for EHRs adding decision support to HIE could potentially yield even greater financial returns	
Kho, *et al.,* 2013[88]	**Over 3 years** -12,748 email alerts on 6,270 unique patients -23% (MSRA) and 22% (VRE) had previous history identified at a different hospital system **10 Infection Preventionists surveyed** -All reported email alerts were useful -Estimated receiving 5 alerts per day; half already known; alerts used to identify patients requiring intervention -3 said system added time, 1 saved time, 6 neutral -Most comment recommendation was to add automate capture of lab data	Low
Kierkegaard, Kaushal, and Vest, 2014[127]	Availability of information varied based on patient consent (required in New York State) and healthcare organization participation. **USE** -MDs had low tolerance for search failures. -Practice staff are important to obtaining patient consent. Where clerks were not trained or supported, fewer patients consented. -Patients saw providers covered by other exchanges, suggesting need for larger areas -Physician use HIE less than other clinical users; MDs often delegate the task. **USABILTY** -Login process perceived as a burden -Slow system response times	Moderate
Lammers, Adler-Milstein, and Kocher, 2014[69]	**Probability of repeat ED imaging (percentage points [95% CI]), relative reduction** CT: -8.7 (-14.7 to -2.7), 59% Ultrasound: -9.1 (-17.2 to -1.1), 44% Chest x-ray: -13.0 (-18.3 to -7.7), 67% -Repeat tests more likely in large EDs	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Lang, *et al.,* 2006[65]	RCT	Impact of sending family physicians electronic vs. mailed reports of ED visits for their patients	Montreal, Canada	ED and family physician practices	**Database** Surveys and determination of patient outcomes	June 2001-April 2002
Lee, *et al.,* 2012[89]	Pre-post implementation survey	To understand MD perception prior to HIE implementation and post implementation use and evaluation	South Korea	Hospital and ambulatory clinics	**Survey, audit logs**	June 2008 Week 1 and 2 (pre survey) Post: NR
Lobach, *et al.,* 2007[100]	Cross-sectional	To describe use of an HIE for population health management	Durham County, North Carolina	Outpatient	**Audit logs**	September 2006-February 2007

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Lang, *et al.,* 2006[65]	Adult university teaching hospital in Montreal	Report of ED visit sent to family physicians	NR	Patients visiting ED during 0800-2200
Lee, *et al.,* 2012[89]	Seoul National University Bundag Hospital and 35 clinics	Federated architecture model with ebXML RS and ebSML RIM standards Included demographics, diagnoses, medications, lab results, imaging, treatment, care plans, vital signs, history and summaries.	June 2008 with updates October 2009	MDs in hospital (50) and clinics (147) for pre; MDs using the HIE for post
Lobach, *et al.,* 2007[100]	Northern Piedmont Community Care Network set up a system called COACH (Community-Oriented Approach to Coordinated Healthcare) includes 32 private practices, 3 federally qualified health centers, 4 community hospitals, 9 government agencies (county health departments and departments of social services), 1 academic medical center, and 2 care management teams: Durham County, North Carolina, Medicaid	The 4 types of data collected by the system include*: 1) administrative (demographics and identifiers, services used, provider associations, audit trails); 2) care management (care management encounters, health risk and environment assessment, socio-economic data, special needs, and care management plans); 3) clinical (encounters, problems/procedures, missed appointments, medications, allergies, laboratory results, disease-specific care plans); and 4) communication (messages and alerts, referrals, notices of new information).	2001	Patients in program

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Lang, *et al.*, 2006[65]	2,022 (out of 3,168) patients visiting ED	Patients visiting ED	Patients in altered mental state (129), state of agitation (21), or with language barrier (29)	ED visit summary provided electronically vs. on paper sent by mail
Lee, *et al.*, 2012[89]	23 from hospital and 48 from 20 clinics (46% and 33% response) for pre; 15 from hospital and 25 from clinics for post out of all MDs using the system	MD at pilot site	<50% of items completed	Hospital vs. clinic based MDs
Lobach, *et al.*, 2007[100]	11,899 patients in Durham County in Medicaid	NA	NA	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Lang, *et al.,* 2006[65]	-Physician satisfaction -Return visits at 14 and 28 days -Duplication of requests for diagnostic tests -Duplication of specialty consult requests - Economic	-Physician satisfaction -Return visits at 14 and 28 days -Duplication of requests for diagnostic tests -Duplication of specialty consult requests	Physicians already are sent carbon copies of first page of ED note; self-report of followup data	**Quantitative** Survey, analysis of followup care
Lee, *et al.,* 2012[89]	-Pre: Perceptions -Post: Information transmission rate Information utilization rate	Setting (hospital vs. clinic based)	-Gender -Age -Specialty	**Quantitative** Fischer exact tests
Lobach, *et al.,* 2007[100]	Sentinel events: resource utilization by patients (events of commission) that were considered excessive (e.g., 3 ED visits in 90 days) or potentially avoidable (e.g., ED visit for asthma) and that could potentially be modified by the involvement of care managers and other providers	None	None	**Quantitative** Counts, observation

Author, Year	Results	Risk of Bias
Lang, *et al.*, 2006[65]	-Reports found to be received, especially in timely manner, and were more likely to be legible, comprehensive, and useful. -No difference in return visits within 14 and 28 days, although near significance for fewer visits for patients >65 years within 28 days. -No difference in duplicate test ordering but greater subspecialty consult requests in intervention group.	Moderate
Lee, *et al.*, 2012[89]	**Pre HIE** -Mean Likert scale that HIE is needed (5 strongly agree): 4.2, p=0.8888 for all and by setting. Similar responses about the need for HIE for specific items (e.g., lab reports) and perceived benefits of HIE. -Hospital based MDs had higher levels of agreement about concerns related to HIE than clinic based MDs **Post HIE** *Most commonly transmitted information differed by setting* From hospital was working diagnosis: 99.5% vs . 70.5% for clinic, p<0.0001 From clinic it was clinical findings: 79.8%, but this did not differ from hospital The most useful was lab or imaging in both settings but it was more frequently rated as useful by hospitals (88.2% and 72.9% of cased p<0.0001)	High
Lobach, *et al.*, 2007[100]	In an analysis of 11,899 continuously enrolled patients from a single county over a six-month period 19.3% (2,285 unique patients) had 7,226 sentinel health events **Frequency of types of events** Hospital admit asthma: 43 Hospital admit diabetes: 76 Low-severity ED: 2, 546 ≥2 missed appointments in 60 days: 1,728 **Implementation lessons** -Political issues are more challenging than technical issues -Perceived value of notices was dependent on timeliness and completeness of underlying HIE dataset. -Difficult to determine who should be notified of these events, how many notices should be resent and how to prioritize them.	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Maass, *et al.,* 2008[61]	Cross-sectional	Ascertain benefits of HIE when they occurred	Finland	Regional information system for exchange of clinical data between hospital and primary care offices	**Survey** Time-motion study of diabetic patients in a health center	NR
Machan, Ammenwerth, and Schabetsberger, 2006[62]	Cross-sectional	Assess value of different aspects of regional network of hospitals and physician practices	Tyrol region of Austria	Regional information system for exchange of clinical data between hospital and primary care offices	**Survey, interviews** Initial qualitative development of survey followed by quantitative evaluation of responses	May-August 2004
Mäenpää, *et al.,* 2011[46]	Retrospective cohort	What is impact of a regional health information system on test ordering and referrals?	Tampere, Finland	Hospital district that includes 1 hospital district and its community health system. Outpatient	**Log file** Usage of HIE and ordering of laboratory and radiology tests as well as specialty referrals	Data collected 2004-2008

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Maass, *et al.,* 2008[61]	Regional information system in Finland	Transmission of patient data into physician EHR	NR	Physicians in health centers in Finland
Machan, Ammenwerth, and Schabetsberger, 2006[62]	Tiroler Landeskrankenanstaleten (TILAK)	Transmission of discharge letters and clinical findings from hospitals to general practitioners. Direct exchange via email.	June 2003	General practitioners in Tyrol, Austria
Mäenpää, *et al.,* 2011[46]	Regional information system in Finland	Full medical record in regional information system	2004	About 234,000 inhabitants in hospital district and associated clinics

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Maass, *et al.,* 2008[61]	20 visits by patients with diabetes	NR	NR	Use of information system and description of benefits
Machan, Ammenwerth, and Schabetsberger, 2006[62]	4 providers followed by cross-sectional survey of 104 of 242 (43%) providers.	All general practitioners in Tyrol	None	None
Mäenpää, *et al.,* 2011[46]	NR	NA	NA	Appointments, ED visits, laboratory and radiology tests for primary and specialty care

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Maass, *et al.,* 2008[61]	Use of information system and description of benefits	System used and benefits described	NA	**Thematic analysis** Time-motion study
Machan, Ammenwerth, and Schabetsberger, 2006[62]	-Measurement of overall satisfaction -Desirability for receiving reports electronically -Reduced work for filing and archiving -Leading to improved quality of care	Survey	NA	**Mixed methods** -Quantitative, descriptive data -Qualitative, content analysis
Mäenpää, *et al.,* 2011[46]	-Rates of laboratory and radiology test ordering -ED visits and primary care referrals	None	Use of HIE not correlated specifically with outcomes	**Quantitative** Log analysis

Author, Year	Results	Risk of Bias
Maass, *et al.,* 2008[61]	20 visits, 4 involved use of information system, with 1 allowing faster treatment decision and 3 providing access to latest test results	High
Machan, Ammenwerth, and Schabetsberger, 2006[62]	**Satisfaction with HIE** Positive: 66.4% Agreeing desirable for receiving all reports electronically: 83.7% Reporting less work for filing and archiving: 82.7% Agreeing it led to improved quality of care: 78.8%	Low
Mäenpää, *et al.,* 2011[46]	**Change in rates of ordering over time (primary vs. specialty care)** Laboratory tests per appointment: 19.0% vs. 7.0% Laboratory tests per inhabitant: 19.0%, 17.9% Clinical chemistry ordering per appointment: 6.6% overall Clinical chemistry ordering per inhabitant: 17.5% overall Radiology exams per appointment: -16.4% vs. -11.0% Radiology exams per inhabitant: -18.9% vs. -1.9% ED visits: -1%, -16.2% Primary care referral to specialist per appointment: 43.6% Primary care referral to specialist per inhabitant: 35.2%	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Mäenpää, *et al.,* 2012[115]	Retrospective cohort	What is usage of a regional health information system for different amounts of test ordering and referrals?	Tampere, Finland	Hospital district that includes 1 hospital district and its community health system	**Audit logs** Usage of HIE and ordering of laboratory and radiology tests as well as specialty referrals	Data collected 2004-2008
Magnus, *et al.,* 2012[47]; Herwehe, *et al.,* 2012[124]	Retrospective cohort	To describe patients identified by the LaPHIE system and HIV-related outcomes associated with LaPHIE over 2 years.	Louisiana	HIV specialty, inpatient and outpatient care within Louisiana State University Health Care Division system. Includes 7 safety net hospitals	**Log file** Alerts for HIV patients that continue to appear until patients receive CD4 or VL testing; actions taken by the provider are documented within the structured EMR	February 1, 2009-July 31, 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Mäenpää, *et al.,* 2012[115]	Regional information system in Finland	Full medical record in regional information system	2004	10 municipalities; About 234,000 inhabitants in hospital district and associated clinics
Magnus, *et al.,* 2012[47]; Herwehe, *et al.,* 2012[124]	Seven safety-net hospitals;	LaPHIE is a secure bi-directional public health informatics application linking statewide public health surveillance data with patient-level EMR data. The exchange functions in real-time throughout the integrated data networks emergency departments, primary care and specialty ambulatory clinics, and inpatient units.	February-September 2009 (Herewhe, 2012)	HIV patients coming to Louisiana State University Health Care Services division clinics or ED.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Mäenpää, *et al.,* 2012[115]	NR	NA	NA	Usage of HIE by physicians, nurses, and department secretaries, and number of appointments, ED visits, and laboratory and radiology tests
Magnus, *et al.,* 2012[47]; Herwehe, *et al.,* 2012[124]	419 patients in 60 clinics; alerts to 223 clinicians	HIV persons identified by LaPHIE with no CD4 or VL monitoring in >1 year, were followed in 6-month intervals for retention in HIV specialty care, inpatient and outpatient healthcare utilization	HIV patients who had been seen within past year and had no break in care of >1 year since diagnosis	Time-matched random sample of HIV-infected persons who had been seen for HIV care within the Louisiana State University Health Care Services Division integrated data network ≥1 within the past 5 years at the time of comparison.

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Mäenpää, *et al.*, 2012[115]	-Rates of laboratory and radiology test ordering -ED visits and primary care referrals	Usage of HIE	Use of HIE not correlated specifically with outcomes	**Quantitative** Descriptive statistics and negative binomial regression
Magnus, *et al.*, 2012[47]; Herwehe, *et al.*, 2012[124]	-CD4 <200 cells/mm^3 -VL >10,000 RNA copies/mL -Having been prescribed antiretroviral treatment during each 6-month interval	Use of LaPHIE	Adjusted for demographic and clinical characteristics and timing of entry into the cohort	**Quantitative** -Chi^2 tests, unadjusted logistic regression, and adjusted logistic regression -Generalized estimating equations using an exchangeable correlation matrix

Author, Year	Results	Risk of Bias
Mäenpää, *et al.,* 2012[115]	**Usage of HIE (views per year)** Physicians: 1,333 Nurses: 758 Department secretaries: 497 -No associations detected between use of HIE and test ordering outcomes **References (means one view of the HIE) viewed in primary health care in 2004–2008:** By physicians from n=486 to n=3581 By nurses from n=59 to n=2,3535 By department secretaries from n=26 to n=13,542 **References viewed in special care in 2004–2008:** By physicians from n=1,496 to n=25,051 By nurses from n=284 to n=20,587 By department secretaries from n=1,156 to n=6,958 -The HIE utilization rates increased annually in all 10 federations of municipalities, and the viewing of reference information increased steadily in each professional group over the 5-year study period. In these federations, a significant connection was found to the number of laboratory tests and radiology examinations, with a statistically significant increase in the number of viewed references and use of HIE. 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.	NA
Magnus, *et al.,* 2012[47]; Herwehe, *et al.,* 2012[124]	"After adjustment for demographic and clinical characteristics and timing of entry into the cohort, the LaPHIE-identified group remained significantly more likely to be immunocompromised (CD4 < 200 cells/mm^3) than their counterparts (OR 3.22, 95% CI 1.72 to 6.04, p<0.001). However, there was improvement over time, with a decrease in odds of having a CD4 < 200 cells/mm^3 at each successive six-month interval (OR 0.91, 95% CI 0.83 to 0.99, p<0.05). VL proved more responsive to changes in treatment and care; LaPHIE-identified persons rapidly became similar to their in-care counterparts, with no significant differences between VL, and again, decreased odds of having a VL > 10,000 copies/mL at each successive interval (OR 0.83, 95% CI 0.73 to 0.93, p<0.01)." 24% of those identified had not had a CD4 count or VL since initial diagnosis. Of remaining 76% who had been in care previously, 55% had been out of care for ≥18 months. Following LaPHIE identification, 42% had CD4 counts < 200 cells/mm^3 and 62% had VL >10,000 RNA copies/mL. Of 344 patients with at least 6 months of followup, 85% had ≥1 CD4 and/or VL after being identified.	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Massy-Westropp, *et al.,* 2005[134]	Cross-sectional	Pilot the effectiveness of electronic data linking tools to assist in the transfer of information between an acute care hospital and the main regional provider of home-based care.	Adelaide, South Australia	Link patient health information between the hospital and community services sector	**Survey, focus group** Email alert to community; remote access to hospital reports; flag community patients; web access to community reports.	Piloted over 6 months 2002-2003
McCarthy, *et al.,* 2014[161]	Multiple case studies	Factors influencing technical architecture, clinical outcomes, and challenges for Beacon-funded HIEs	Regions within Maine, Indiana, Ohio, Washington, Pennsylvania, Oklahoma, New York	Any	**Interviews** Written and telephone interviews of implementers of 7 HIEs	NR
McCullough, *et al.,* 2014[135]	Cross-sectional	To assess barriers and benefits to HIE participation in 2 underserved settings	San Gabriel Valley, California and Minneapolis St. Paul, Minnesota	Outpatient small practices (California) and federally qualified health centers (Minnesota)	Interviews of clinicians, administrators and office staff users	NR
McGowan, *et al.,* 2007[148]	Cross-sectional	To ascertain lessons learned in the development of Vermont's RHIO	Vermont	NR	Interviews and documents and presentations about the development of VTMEDNET	NR

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Massy-Westropp, *et al.,* 2005[134]	Public teaching hospital, ED and aged home-based care community services organization.	Email alert to community; remote access to hospital reports; flag community patients; web access to community reports.	Piloted over 6 months 2002-2003	Medical, nursing, and allied-health staff across the organizations
McCarthy, *et al.,* 2014[161]	Beacon Communities within Maine, Indiana, Ohio, Washington, Pennsylvania, Oklahoma, New York	Varied from hybrid-federated to centralized	1994-2009, depending on HIE	Operational, technical, and clinical leaders of each HIE
McCullough, *et al.,* 2014[135]	Citrus Valley Health Partners Federally Qualified Health Center Urban Health Network (FUHN)	California: Collaborate system. a web-based tool enabling all providers to view data exchanged from 3 hospitals, an anticipated 90 providers, and laboratories in the community and to securely message other providers. Data are available to be viewed by all participating providers, regardless of whether a physician is contributing data to the system. Minnesota: CentraHealth aimed at enabling electronic exchange between FQHCs and the hospitals serving their Accountable Care Organization patients. This system was in implementation at time of study	NR	Independent practices serving predominately Hispanic patients and federally qualified health centers developing an accountable care organization
McGowan, *et al.,* 2007[148]	VTMEDNET (early HIE) and more recent statewide RHIO	Federally funded (NLM and AHRQ) initiated by hospitals, but developed by a coalition. No other detail provided	NR	NA

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Massy-Westropp, *et al.,* 2005[134]	82 medical, nursing and allied-health staff. HIE included up to 4,000 patients. Satisfaction survey responses from 55 or 132 nurses, clinicians and allied health staff.	NR	NR	82 respondents of HIE project vs. 50 care providers outside of the HIE project
McCarthy, *et al.,* 2014[161]	7 HIEs funded by Beacon Community grants	NA	None	Compared various factors across hybrid-federated vs. centralized HIEs
McCullough, *et al.,* 2014[135]	N=24 providers, administrators, and office staff in 16 sites	Individuals who would be involved in adoption decisions and integration of HIE into workflows at each organization	None	None
McGowan, *et al.,* 2007[148]	5 interviews: 2 CIO of hospitals and 3 key leaders	NA	NA	Description of 2 efforts. Some limited comparison of the 2

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Massy-Westropp, *et al.,* 2005[134]	Satisfaction with electronic data linking	NA	NA	**Mixed methods** -Quantitative, descriptive statistics -Qualitative, content analysis
McCarthy, *et al.,* 2014[161]	-Trust -EHR context -Clinical transformation -Clinical research	Qualitative	NA	**Qualitative** Interviews
McCullough, *et al.,* 2014[135]	Benefits and barriers to HIE use	NA	NA	**Qualitative** Thematic analysis from transcripts
McGowan, *et al.,* 2007[148]	Facilitators and barriers to creation and implementation	NA	NA	**Qualitative** Simple summary of interviews

Author, Year	Results	Risk of Bias
Massy-Westropp, *et al.,* 2005[134]	Provided bar graphs (figures 2 and 3) but not specific quantitative results except for a statement about use and satisfaction. 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.	High
McCarthy, *et al.,* 2014[161]	Hybrid-federated models maintain autonomy, accommodate disparate EHRs, and build incrementally, while centralized models require trust fabric, leverage common EHRs, and while providing long-run cost-efficiency may require larger upfront investment. Hybrid-federated models provide most functionality at individual organization level while centralized models leverage value of communitywide data and usage.	Moderate
McCullough, *et al.,* 2014[135]	Barriers -Lack of well-functioning area-level exchange -Market characteristics -Relationships or previous experiences with exchange partners -Challenge achieving a critical mass of users -Health IT used -Data ownership and provider liability concerns Benefits -Improved productivity at initial visit -Improved completeness of records -Avoidance of duplicative services/patient financial risk -Improved nonvisit consults	Low
McGowan, *et al.,* 2007[148]	**Major facilitators for success** -Public awareness -Provider buy-in -Benefits understood in terms of patient safety and quality of care **Barriers** -Perceived public perception of privacy issues -Providers lack working knowledge of HIE concepts -Need for a sustainable business model is recognized but not solved -Need for health information to cross state lines	High

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Merrill, *et al.,* 2013[174]	Time series	Evaluate the complex dynamics involved in implementing electronic HIE for public health reporting at a state health department, and to identify policy implications to inform similar implementations	New York	State health department, 3 RHIOs	**Interviews, documents** Lab results and other information for rapid and efficient identification, monitoring, investigation, and treatment of communicable and emerging diseases	2010-2011
Messer, *et al.,* 2012[138]	Before-after	(1) Assess and enhance organizational readiness to adopt information technology, (2) develop a RHIO to share electronic data between medical and ancillary care providers, (3) implement the RHIO and begin active information exchange and (4) evaluate the effect of the intervention on provider-related attitudes and satisfaction with information exchange	North Carolina	Ambulatory HIV providers and ancillary care providers	**Interviews** -Pre-post survey -HIV patient data and lab results	2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Merrill, *et al.*, 2013[174]	3 RHIOs and New York State Department of Health.	Lab results and other information for rapid and efficient identification, monitoring, investigation, and treatment of communicable and emerging diseases	August 2007-August 2011	Not described but patients who would be reported to the health department for risk and disease.
Messer, *et al.*, 2012[138]	Carolina HIV information cooperative regional health information organization (CHIC RHIO)	1 large academic medical center and 5 AIDS service organizations. Used CAREWare from HRSA. Federated, query-based exchange.	2008 organization begun	HIV care providers and ancillary service providers

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Merrill, *et al.*, 2013[174]	NR	NR	NR	NA
Messer, *et al.*, 2012[138]	1 large academic medical center and 5 AIDS service organizations mostly providing case management. Interviews and assessment with 39 stakeholders; pre and post survey of 29 providers' satisfaction with HIE, relationships with other providers, barriers.	Leaders of the individual organizations, HIV providers	NA	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Merrill, *et al.,* 2013[174]	Descriptive narrative only	NA	NA	**Qualitative**
Messer, *et al.,* 2012[138]	-Organization readiness for Charge measure -Qualitative process summary -Provider surveys of effectiveness	NA	NA	**Mixed Methods** -Quantitative, descriptive data -Qualitative, theme analysis from transcripts.

Author, Year	Results	Risk of Bias
Merrill, *et al.,* 2013[174]	Three casual loop diagrams captured well recognized system dynamics: Sliding Goals, Project Rework, and Maturity of Resources. The findings were associated with specific policies that address funding, leadership, ensuring expertise, planning for rework, communication, and timeline management.	Low
Messer, *et al.,* 2012[138]	-Organizational readiness assessment found organizations were well prepared to adopt new technology, in the 4 domains (motivation, adequacy of resources, staff attributes, and org climate) only motivation was slightly below nationally determined levels. Results were consistent by agency type and respondent type -Largely positive response to quality process. Improved sense of mission, more contact with other agencies, better awareness of other agency roles. -Providers found increased case manager knowledge of medical care -Concerns: Initial concerns about confidentiality dismissed 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 -Quantitative provider survey: AIDS service organizations and medical providers generally both felt increased ease of data exchanged and that patient care improved. For AIDS service organizations 7/8 satisfaction related questions improved statistically from pre-post, in clinic survey 4/8 improved statistically	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Miller, 2012[162]	Multiple case studies	Assessed how well 5 diverse California health care entities' HIE capabilities, policies, and procedures satisfied the patient and consumer principles as of early 2011.	California	A captivated integrated delivery system (Kaiser); a physician management service organization (Nautilus); a large public hospital; a large Medicaid HMO; a regional HIE organization	**Interviews** EHR, Patient portal, HIE, administrative, inpatient, outpatient. Patients' medications, allergies, chronic disease diagnoses, history, and lab results. Providers could also view hospital radiology reports.	August 2010-April 2011
Miller and Tucker 2014[149]	Cross-sectional	How does size of user (hospital health system or network) affect HIE usage?	U.S.	Health systems and networks	**Survey** Hospital Electronic Health Record Adoption Database (AHA, funded by ONC and is intended to be the most comprehensive and representative survey of the state of healthcare IT)	2007-2009

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Miller, 2012[162]	1 capitated integrated delivery system (Kaiser); a physician management service organization (Nautilus); a large public hospital; a large Medicaid HMO; a regional health information exchange organization	Each of the 5 systems had their own HIE. Some used EPIC, Next Gen, Siemen's NetAccess, Axoloti's Elysium HIE software	NR	NR
Miller and Tucker 2014[149]	Various	Various, within-system and out-of-system HIE	Various	U.S.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Miller, 2012[162]	N=5 organizations; 23 interviews with 18 people	NR	NR	They compared against 9 principles e.g., important benefits for individual health; important benefits for population health; inclusivity and equality; etc.
Miller and Tucker 2014[149]	430 hospital systems, 4,060 hospitals; average system contains 6 hospitals and operates in just under 4 regional markets	NR	None	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Miller, 2012[162]	Discussed each principle and how well it was met	NA	NA	**Qualitative** Descriptive
Miller and Tucker 2014[149]	Self reported internal or external exchange of data by hospitals	System's size, defined as the number of hospitals owned, leased, sponsored or contract-managed by a central organization	Patient flow, insurance status (Medicaid, Medicare fractions) per capita payroll, physician relationship (independent practice association, group practice, integrated salary model); profit/nonprofit status; specialty vs. general; IT vendor (HIE capability), EMR age	**Quantitative multivariate analysis** Unit of analysis is hospital, logistic regression p (exchange) = system size, etc.

Author, Year	Results	Risk of Bias
Miller, 2012[162]	Discussed each principle. Also discussed challenges and barriers.	Moderate
Miller and Tucker 2014[149]	**68% do internal exchange:** HIE increases with system size; each additional hospital in system increases likelihood by 2 percentage points; increase if nonprofits, decrease w/ more Medicaid, Medicare, unaffected by location in U.S., age of technology, vendor **17% do external exchange:** larger hospital systems are less likely to exchange information externally. Each additional hospital in a system lowers the chance of external data exchange from hospitals in that system by 0.7 percentage points. Not affected by relative number of outside hospitals; more sharing with number of beds, number of doctors, % Medicare, per capita payroll; regardless of age of system or size of vendor -Robust to type of data (demographic or clinical); -No relation to HMO, PPO, etc.; -Same effects stronger with higher per capita salaries, suggesting some strategic benefit	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Moore, *et al.,* 2012[106]	Cross-sectional	To describe the status and lessons learned from the development and establishment of an HIE based system to alert ambulatory providers when their patients are admitted or discharged from the hospital or ED.	New York City	Hospital, ED, and out patient	**System logs**	November 1, 2010-April 30, 2011 (6 months)
Myers, *et al.,* 2012[128]	Multiple site case studies	Describe how members of HIV patients' care teams perceived usefulness and ease of use of newly implemented, innovative HIEs in diverse HIV treatment settings.	Urban settings and 1 suburban setting in New York, New Jersey, Louisiana, California, North Carolina	Hospital specialty clinics, support services, primary care clinics, testing sites, ED, outpatient and inpatient clinics, Office of Public Health, insurers, laboratory and pharmacy services	Survey and interviews during site visits. Laboratory, diagnostic, medical, and service utilization; referrals; and ancillary care support, such as case management, counseling and testing, transportation, and substance use and mental health services	July 2008-December 2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Moore, *et al.,* 2012[106]	New York Clinical Information Exchange (NYCLIX)	-An event detection and notification system based on a RHIO including major medical centers, primary care physicians, a home health care agency, long-term care facilities and a Medicaid managed care plan -NYCLIX uses a federated architecture in which the clinical repository is spread over a collection of “edge servers” that reside in each of the members’ data centers. -Alerts are considered 1-to-1 communication between providers and are limited to name, date and location of service, so patient consent was not required	November 2009	63,305 patients enrolled from 3 hospitals
Myers, *et al.,* 2012[128]	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, NY Presbyterian Hospital, St. Mary Medical Center Foundation. Query-based	5 HIEs, each site designed, tailored, and implemented enhancements to existing HIEs according to local needs	NR	Members of HIV patient care teams

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Moore, *et al.*, 2012[106]	NR	NA	NA	NA
Myers, *et al.*, 2012[128]	60 case workers, medical providers, nonclinical staff. 62 of 102 responded (62%)	Medical providers, case managers and nonclinical members of the participating HIE organizations	NR	Comparison by type of responder

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Moore, *et al.*, 2012[106]	Number of events detected overall and per patient	NA	NA	**Quantitative** Descriptive statistics
Myers, *et al.*, 2012[128]	-10-item perceived ease of use -10-item perceived usefulness	Role	NR	**Mixed methods** **Quantitative:** Descriptive statistics stratified by role and analysis of variance comparison by role **Qualitative: Thematic** analysis of the qualitative data interviews were organized

Author, Year	Results	Risk of Bias
Moore, *et al.*, 2012[106]	-42,818 events detected, on average 238 per day -≥1 event: 6,913 patients -1 event: 1,879 patients -≥10 events: 623 patients -Mean events of inpatients who had an event: 7.7 events -Mean events of all patients: 0.7 events	Moderate
Myers, *et al.*, 2012[128]	Quantitative: vs. medical providers (57%) and case managers (39%) nonclinical staff members (12%) were significantly less likely to report that they provided input into the design of the HIE (p <0.008). Mean composite for ease of use was high (3.9/5.0) and no difference by role. Mean composite for usefulness was also high (4.0/5.0) 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.	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Nagykaldi, *et al.,* 2014[48]	Retrospective cohort	Describe a pilot study on a more sophisticated architecture that may provide a preliminary roadmap for building HIE with intelligence.	Central Oklahoma	30 primary care practices, several specialty practices, and the Norman Physician Hospital Organization including an academic hospital and 11 other major hospitals.	**Log file** Specialty referrals, hospital admissions, prescriptions, laboratory imaging results, and emergency care	March 2010-June 2012
Morris, *et al.,* 2012[163]	Multiple Case Studies	To understand the lessons learned from HIE organizations and projects that have succeed and those that have failed.	U.S. States	Multiple	Interviews and Surveys	Not reported

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Nagykaldi, *et al.,* 2014[48]	exHUB SMRTnet is a statewide network that includes 120 healthcare organizations.	Comprehensive patient registry and clinical decision support tool and reminder system for preventive care and chronic disease management. Preventive Services Reminder System	NR	346 patients from 6 primary practices. Average age 66.3 years, 67.1% female, 20% ethnic minority
Morris, *et al.,* 2012[163]	Closed HIOs include CareSpark. Consolidated HIOs include Minnesota HIE (MN HIE) and Galveston County HIE. Additional HIOs were studied but declined to be included in the public report. Successful HIOs include: Chesapeake Regional Information System for Our Patients (CRISP), Delaware Health Information Network (DHIN), HealthInfoNet, Indiana Health Information Exchange (IHIE), Michiana Health Information Exchange, and Rochester RHIO.	All query based	Varies	Query based HIE project in U.S.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Nagykaldi, *et al.,* 2014[48]	346 patients	NR	NR	Before and after HIE
Morris, *et al.,* 2012[163]	9 HIEs provided data that they permitted to be reported publicly.	HIE organizations that ceased operations, merged or continued to operate at the time of the study	HIE organizations that refused to have their information made public	Successful to failed HIE organizations

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Nagykaldi, *et al.,* 2014[48]	-Time-motion studies -Complete documentation on preventive screenings and flu vaccinations -Medication reconciliation	Before and after SMARTnet employed	NR	**Quantitative** Descriptive
Morris, *et al.,* 2012[163]	Whether the HIE organization continued to operate	Ability to make changes to technology Ambulatory practices participation Payers participation Months to deployment Months to live data Months to live clinical data	NA	Qualitative

Author, Year	Results	Risk of Bias
Nagykaldi, *et al.,* 2014[48]	**All increased significantly (p<0.001 from pre to post)** Completed mammograms: 22.1% to 57.1% Recommended colonoscopies: 31.7% to 53.8% Pneumococcal immunization: 39.1% to 50.6% Influenza immunization: 22.7% to 41.7% Medication reconciliation (defined as the ratio of matching practice records and patient reports before and after the HIE implementation): 35.3% (370 of 1047) to 44.9% (468 of 1043) **Barriers included:** delays and difficulties in collaborating with commercial technology vendors who gave innovation a low priority **Facilitators included**: strategic planning, shared goals, and establishing communication methods	Moderate
Morris, *et al.,* 2012[163]	Facilitators: Key to successful implementation is abilities to move beyond pilot to have volume and breadth of data: id early adopters who find value and get to a high number of queries, records returned. Successful HIE projects seem to be those that have some level of control over the technology they use. Sustainability is related to the ability of HIE organizations to innovate and react quickly to changes in markets. This requires a combination of leadership and technology.	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Nøhr, *et al.,* 2001[139]	Before-after	Compare expectations with experiences after HIE launched	Denmark	Hospitals and primary care	**Survey, interviews**	1999
Nykänen and Karimaa, 2006[150]	Cross-sectional	Factors of success and failure for a regional IS network of hospital and physician offices	Finland	Regional information system for exchange of clinical data between hospital and primary care offices	**Interviews and documents** Study of HIE documents and processes; interviews of users in pilot phase	NR
Onyile, *et al.,* 2013[125]	Cross-sectional	Determine the geographic distribution of patients using the New York metro RHIO	New York	Multiple settings	**Database and Audit logs** Ambulatory physician groups, long-term care facilities, a Medicaid managed care plan, the nation's largest home health-care provider and academic medical centers that serve as major referral centers with a total of 7,503 inpatient beds, 341,065 annual inpatient discharge and 540,854 annual ED visits	Cumulative: 2009-2011 (patients entered by time of study, 2011)
Overhage, Evans, and Marchibroda, 2005[151]	Cross-sectional	Community readiness for HIE.	U.S.	Various	**Survey** Web based survey for Connecting Communities for Better Health	2004

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Nøhr, *et al.,* 2001[139]	Varies as this was a national effort in Denmark	Four types were described: Common database EDI: copies of data are transferred between systems Middle ware: software between application and database Internet technology: data communicated via browser	1998 to 1999	Not reported
Nykänen and Karimaa, 2006[150]	Regional information system in Finland	Not well-described	NR	Pilot users of system
Onyile, *et al.,* 2013[125]	New York Clinical Information Exchange (NYCLIX) - Manhattan based RHIO	NYCLIX - Manhattan based RHIO, ambulatory groups, long term care, home health care, academic health centers, Medicaid managed care plan	March 2009	Patients who visited a NYCLIX facility
Overhage, Evans, and Marchibroda, 2005[151]	Various	Various	NA	Organizations and individuals who might be interested: 839 (national associations: 110, government agencies: 57, individuals: 117, national organizations: 354, state-focused organizations: 201)

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Nøhr, *et al.*, 2001[139]	Survey respondents: Expected benefits in 1998 (n=102); Experiences in benefits in 1999 (n=57); Expected barriers in 1998 (n=101); Experiences in barriers in 99 (n=99)	Seven persons involved in each HIE project.	NR	Expectation vs. Experience. Also comparison to paper systems at times.
Nykänen and Karimaa, 2006[150]	Unspecified number	NA	None	None
Onyile, *et al.*, 2013[125]	3,980,016 patients (after excluding 26,589 with invalid zip code)	In RHIO master patient index	Invalid zip code	NA
Overhage, Evans, and Marchibroda, 2005[151]	134	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Nøhr, *et al.,* 2001[139]	Expected benefits and barriers. Experienced benefits and barriers.	NA	NA	**Mixed Methods** -Quantitative, descriptive data -Qualitative analysis
Nykänen and Karimaa, 2006[150]	Perform work tasks and how the HIE changes them	Qualitative	NA	**Qualitative** Interviews, observations, usability, and analysis
Onyile, *et al.,* 2013[125]	Visited RHIO facility (in master patient index)	Calculated distance from Times Square	NR	**Quantitative** Mapped the most current zip code for each unique patient to the appropriate U.S. county, calculated the distance from each zip code to Times Square, mapped with EpiInfo v3.5.3, spatial regressions with SatScan v9.1.1 and RR of visit by spatial cluster
Overhage, Evans, and Marchibroda, 2005[151]	None	NA	NA	**Quantitative** Descriptive - provide only percentages

Author, Year	Results	Risk of Bias
Nøhr, *et al.,* 2001[139]	"What was expected, but not found, was resistance to EPR, as a result of changes in skills and power. The most obvious benefits are increased data accessibility and improved decision making. The most considerable disadvantage is an enormous growth in discontent with the systems performance and the fact, that all the projects are delayed. Many different types of integration solutions are chosen, because of a lack of a common model for integration. Generally the projects find, that EPJ yields increased security, but logistical problems arise in having the systems running 24 hours 7 days a week"	Moderate
Nykänen and Karimaa, 2006[150]	Quality of design process deemed a success factor. General statement that users experienced better planning of patient care and access to data, but no details given.	Moderate
Onyile, *et al.,* 2013[125]	NYCLIX has representation in all 50 U.S. states, 4 U.S. territories and 57 International standards organization countries. 12.1 visits/ 100 within 30 miles; 0.4 visits/ 100 at 100 miles; 87.7% live within 30 miles of Times Square; "inflection point" where visits are less than 1 per 100 is 80 miles from Times Square; for cluster counties, RR for visit is 14.4; 77.7% of entire U.S. counties represented; more patients from outer boroughs than from Manhattan	Low
Overhage, Evans, and Marchibroda, 2005[151]	-22% in beta stage, 28% in pilot, 28% operational, 22% conceptual; of 64 self-reported operational, only 9 could be verified -5% no organizational structure; 28% "loose affiliation"; 29% had corporate structure; of these 23% hospitals, 16% provider organizations, 10% academic medical centers, 9% dedicated community HIE, 2% public health -Long lists of organizations to be involved, without actual details of roles; clinicians heavily involved in all, leading the way in 24%; architectures 2% PHR, 20% peer to peer, 3% federated, 54% centralized database; 18% not decided; most planned centralized; broad functionality and data inclusion proposed by participants, without specifics about implementation -Standards proposed: 82% ICD-9, 73% CPT4, 38% LOINC, 41% SNOMED, 48% NDC -One third had identified funding; planned funding over 60% external, 45% subscribers	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Overhage, Grannis, and McDonald, 2008[49]	Retrospective cohort	Compare the completeness and timeliness of laboratory reporting for public health in manual and electronic systems	Marion County, Indiana	Marion County, Indiana (public health system)	**Log file** Indiana Network for Patient Care: 9 of 13 hospitals in county, physician practices, laboratories, radiology centers, public health departments	First quarter of 2001
Ozkaynak and Brennan, 2013[129]	Multiple site case studies	To describe sociotechnical system in terms of social structure determination of technical forms: "how social systems define technology and its usefulness."	Madison, Wisconsin	3 EDs in different systems in same metropolitan area	**Observations, interviews** 210 hours direct observations, varied across shifts, in 5 rounds, by 1 or 2 observers (industrial/ systems engineers, nurses,), with informal conversations to enquire and followup, plus 13 open ended HIE interviews	2008-2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Overhage, Grannis, and McDonald, 2008[49]	Indiana Network for Patient Care (INPC) automated public health reporting based on LOINC codes	Indiana Network for Patient Care: 24 hospitals, physician practices, laboratories, radiology centers, public health departments in Indiana	NR	County wide public health
Ozkaynak and Brennan, 2013[129]	NR	Clinicians choose when to use HIE, which is always available	NR	ED clinicians

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Overhage, Grannis, and McDonald, 2008[49]	Marion county population	Notifiable condition in eHIE system or in manual system(s)	No match of identifiers	Manual public health reporting by physician offices, laboratories (in and out of Indiana) to state and local public health departments, case finding
Ozkaynak and Brennan, 2013[129]	184 patient care episodes	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Overhage, Grannis, and McDonald, 2008[49]	-Completeness -Timeliness of public health laboratory reporting	Electronic or manual reporting system	NR	**Quantitative** Number identified in eHIE vs. number identified by manual reporting, time to reporting
Ozkaynak and Brennan, 2013[129]	-Use of HIE -Views of clinician-users	NA	NA	**Mixed methods** -Quantitative descriptive -Qualitative analysis -Inductive iterative analysis, systems engineers, nurses, physician

Author, Year	Results	Risk of Bias
Overhage, Grannis, and McDonald, 2008[49]	Overwhelming positive effect: 4,635 found by eHIE, 944 by manual; for 818 identified by both, eHIE reported 7.9 days earlier on average, across 53 conditions, eHIE found more for all but 3 conditions; 5/18 data items more often present in manual, 10/18 more often present in eHIE; but false matches (4 Ebola); nondisease positives (rubella screen); repeat testing known positives; delayed report till confirmed or typed (Shigella)	Low
Ozkaynak and Brennan, 2013[129]	-184 patient care episodes (10 use the HIE system, about 5%) -2 unexpected uses of the HIE: (1) The HIE was being used mostly for patients only with specific characteristics. (2) The information from the HIE could be used to confront with the patients. -System used mainly for patients with chronic pain to check previous visits (and prescribing); workflow issues interfered; extra time and effort expended when needed, -When the observers asked the reason of use of the system, the reason mentioned by the majority of the interviewed clinicians was to detect drug-seeking behavior	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Pagliari, Gilmour, and Sullivan, 2004[122]	Multiple case studies	To explore the processes and outcomes of implementation, barriers and facilitators to system adoption and benefits and drawbacks for professional users.	Scotland	Primary and Secondary Care	**Survey responses from users and project managers, interviews, and document review**	November 2001 - May 2003; (August 2002-May 2003 for minimum dataset)

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Pagliari, Gilmour, and Sullivan, 2004[122]	Electronic Clinical Communication Implementation Program (ECCI)	The ECCI is a program initiated as part of the Scottish National health Service Information Management and Technology strategy. It targets six electronic deliverables relating to direct hospital outpatient appointment booking from primary care, referral from primary to secondary care, results reporting from secondary care laboratories to primary care, transfer of hospital discharge and clinic letters to primary care and clinical email.	2000	16 Scottish Health Board areas included in minimum dataset; Survey - in-depth studies of 7 regional sites, chosen to represent the others in terms of geographic and demographic spread and initial IM & T maturity.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Pagliari, Gilmour, and Sullivan, 2004[122]	16 Scottish Health Board areas included in minimum dataset; Survey - in-depth studies of 7 regional sites, chosen to represent the others in terms of geographic and demographic spread and initial IM & T maturity; 64% survey response rate for primary care; 34% for specialty care. Survey sample represents 17% of Scottish practices; therefore respondents represent 11%.	Minimum dataset: all 16 areas; surveys - limited to 7 regions	see inclusion criteria	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Pagliari, Gilmour, and Sullivan, 2004[122]	6 electronic deliverables: 1) direct hospital outpatient appointment booking from primary care; 2) referral from primary to secondary care; 3) results reporting from secondary care labs to primary care; 4) transfer of hospital discharge and clinic letters to primary care; clinical email (second opinion correspondence)	NA	NA	Qualitative Minimum dataset: descriptive statistics Surveys: mailed or email

Author, Year	Results	Risk of Bias
Pagliari, Gilmour, and Sullivan, 2004[122]	From the minimum dataset: GP practices with access to e-results reporting software: 37% GP practices using e-RR: 36%; GP practices with access to e-OP appointment booking system: 3%; GP practices using e-OP system: 2%; GP practices with access to e-referral system: 47%; Referral letters e-transmitted: 18%; GP practices using clinical email: 9%; Consultant led departments using clinical email: 5%; Hospital wards able to send e-discharges: 10%; Wards generating and sending e-discharges: 7%; Specialties able to generate e-clinic letters: 11%; Specialties generating and sending e-clinic letters: 3%. Surveys - of responding practices: 93% used e-Lab results; 58% e-referrals; 42% e-discharges; 16% e-OP booking; Percent reporting daily or weekly use: 90% e-results; 96% e-discharges; 92% e-referrals; 28% e-OP booking. Clinicians most common users of e-reporting/e-referrals; admin/clerical staff most common users of e-discharge/e-OP booking. Implementation was facilitated by successful engagement of stakeholders that focused on proactive methods. Other facilitators were ease of use, good training, communication and commitment from staff. Barriers included differences in IT and system bugs or problems and slow system development.	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Park, *et al.,* 2013[63]	Cross-sectional	To assess patients' perception of an HIE which includes patients' preferences regarding information exchange operations, endorsement of the technology, and expected and perceived benefits and concerns about the technology, and to examine the influence of demographic characteristics and HIE experience on patients' perceptions.	South Korea	Tertiary care and affiliated clinics	**Survey** interview pre-, telephone post-	2008-2009
Patel, *et al.,* 2013[91]	Cross-sectional	To provide national estimates of physician capability to electronically share clinical information with other providers and to describe variation in exchange capability across states and EHR vendor.	U.S.	Out patient	**Survey** -2011 National Ambulatory Medical Care Survey -Electronic medical record supplement	2011
Phillips, *et al.,* 2014[164]	Multiple case studies	Study 3 RHIOs implementing a public health use case	New York	Any, but this study focused on public health reporting and querying	**Interviews and documents** Semi-structured interviews and review of documentation of RHIO	NR

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Park, *et al.,* 2013[63]	Korean HIE pilot	Federated architecture, stores and transfers HL7 CDAs CDA exchanges between referring providers and SUNBH	June 2008	All patients visiting tertiary hospital and affiliated clinics
Patel, *et al.,* 2013[91]	Several	Varies	Varies	Nonfederal office–based physicians who provide direct patient care
Phillips, *et al.,* 2014[164]	3 RHIOs in New York state	All types	Varying	Interviews with leaders of the 3 HIEs

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Park, *et al.,* 2013[63]	Pre: 322 hospital + 408 clinic; Post: 306 of 536 HIE participants, 180 offline information exchange, 208 referral letter only	Not explicitly stated (visited hospital or clinic)	Not explicitly stated	1) paper based, offline (USB stick) and online (HIE); 2) participants and non participants,3) before and after implementation
Patel, *et al.,* 2013[91]	4,326 respondents (61% weighted response rate)	Out patient MDs	Federal physicians	NA
Phillips, *et al.,* 2014[164]	NA	NA	None	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Park, *et al.,* 2013[63]	-Need for HIE -Experience with HIE -Preferences -Endorsement -Perceived benefits and concerns -Satisfaction	HIE exposure status (pre, post, offline, letter)	Demographics	**Quantitative** Descriptive, MANOVA
Patel, *et al.,* 2013[91]	Reported capacity for exchange of pharmacy, lab and clinical summary information	-State -Physician demographics -Physician use of EHR -Practice characteristics -EHR vendor	NA	**Quantitative** '-t-tests -Profit regression models
Phillips, *et al.,* 2014[164]	Certification and becoming operational for public health use case	Qualitative	NA	Qualitative

Author, Year	Results	Risk of Bias
Park, *et al.,* 2013[63]	-Group A (offline 'HIE') older, more likely to have operation, inpatient care; 14% used USB, etc., 10% paper HIE; only 23% concerned MD do not know about prior care; all preferred consent based HIE, 80% in HIE, 55-59 in non-HIE; -Post: satisfied, would recommend: 92% of HIE, 88% of non HIE; HIE and offline 'HIE' equally cited convenience, expedited care; all endorsed HIE, HIE group most strongly; all cited convenience, expedited care, HIE group most strongly; HIE group less concerned about privacy, complexity, inconvenience - A higher percentage of HIE patients (80%) compared with A(55%) & B(59%) reported their preferred method of information exchange was HIE -In general those who experienced HIE had statistically higher rates of agreement with survey questions regarding need for HIE	Low
Patel, *et al.,* 2013[91]	**Overall:** 31% could share clinical summaries, of these 76% could both send and receive, 64% of these exchanges were through an EHR vendor and 28% through a hospital-based system. 55% could e- prescribe, 67% could view lab results, 42% could incorporate lab results into EHR. **State differences:** the capacity to electronically exchange clinical summaries with patients varied from 55% (Minnesota) to 18% (Louisiana). The proportion of physicians who exchange clinical summaries with other providers varied from 61% (Wisconsin) to 15% (Alabama). -Adoption of EHR is strongest practice characteristic associated with exchange capacity, p<.001 -EHR vendors have a wide range of capacities for exchange: 24% to 77% of MDs report exchange capacity by vendor -Primary care providers were more likely to exchange vs. specialists, age of MD was NS	Low
Phillips, *et al.,* 2014[164]	2 common factors influenced risk management and implementation success: leadership capable of agile decision-making and commitment to a strong organizational vision	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Pirnejad, Bal, and Berg, 2008[152]	Cross-sectional	How are data integration and data integrity attained in a communication network?	Almere, the Netherlands	Community - hospital interface	**Interviews, observations, documents** Interviews (pharmacist focus); documents, observations of pharmacist work after implementation	2005-2006
Poulidi, 1999[165]	Multiple Case Study	To review the lessons learned in the context of HIE related to collaboration among stakeholders	United Kingdom	National Health Care system wide	In depth interviews used to create a stakeholder analysis; comparison to an analysis complete in the U.S.	Post 1996, but not reported

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Pirnejad, Bal, and Berg, 2008[152]	Trans-mural exchange of medication data in Almere (TUMA)	Medication information exchange community GP/pharmacist with hospital pharmacy; same vendor, different systems, shared server	2005	Hospitalized people in Almere, Netherlands
Poulidi, 1999[165]	NHSnet	Wide area networking was set up to facilitate the exchange of administrative, purchasing and clinical data.	1993	UK, sub areas not specified

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Pirnejad, Bal, and Berg, 2008[152]	0 of 115 GPs, 2 of 17 community pharmacists, 4 hospital pharmacists in 1 hospital pharmacy; project lead and 2 managers	None given	None given	Pre-post
Poulidi, 1999[165]	NR	NR	NR	Greater Dayton Area Community Patient health Information Network in the U.S.

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Pirnejad, Bal, and Berg, 2008[152]	Second stage: changes in work, improvement, problems; after network tested, reasons for problems in test results	First stage: study context, medication data communication, information gaps	NA	**Qualitative** -Grounded theory -Semi quantitative, formative
Poulidi, 1999[165]	Stakeholder perceptions and attitudes	NA	NA	Qualitative

Author, Year	Results	Risk of Bias
Pirnejad, Bal, and Berg, 2008[152]	-Pitfalls and information gaps in the old medication data communication: missing medication information on admission, delay in information at discharge, dependence on patients for prescription information -TUMA effect on bridging the information gaps and improving the communication, focusing on the test results and their analysis. -Important unforeseen problems: (a) technical challenges in system interface (though same vendor); (b) data integrity problems (59 errors in 32/100 records before fix, 55 items in 14/100 records after fix); (c) problems with coding system and its application, with software and its application, (d) and conflicts related to the articulation work and responsibility distribution between the involved parties - e.g. coding differences by GPs and pharmacists -Aim was to replace patient as weakest link - learned that instead "contribution of patients in saving the integrity of data and in integrating medication data is valuable"	Moderate
Poulidi, 1999[165]	Confidentiality was a major concern for physicians and a barrier that slowed implementation. The NHS case is more complex than the regional US case in that more types of stakeholders are involved, more settings are involved in the NHS implementation and the scope of the data exchanged is greater.	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Ross, *et al.*, 2010[167]	Multiple case studies	Elucidate perspectives of clinical and administrative leaders in smaller ambulatory practices regarding desired HIE functions, key motivators, barriers to and potential incentives for adoption.	Colorado	SNOCAP-USA Practice-based Research Networks; small to medium-sized practices (<20 providers) in primary care practices	**Interviews** -Topic guide created based on literature -Telephone and on-site guided discussions	November 2008-April 2009
Ross, *et al.*, 2013[50]	Retrospective cohort	Does HIE affect laboratory and radiology test ordering	Mesa County, Colorado	Physician offices - outpatient	**Log file** Claims data	April 2005-December 2010
Rudin, *et al.*, 2009[153]	Cross-sectional	What are providers' decision-making processes in implementing HIE?	Massachusetts	Physician offices	**Interviews** Semi-structured interviews	Summer-Fall 2007

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Ross, *et al.*, 2010[167]	1) Community-wide HIE - currently exchanged information, but could use paper or electronic medical records; 2) Paper charts only - No use of community-wide HIE; 3) EMR only - No use of community-wide HIE.	2 types of community-HIE: 1) traditional RHIO that provides limited EMR functionality that includes storage and retrieval of tests, dictations, meds, allergies, e-prescribing (2 urban (1 indigent clinic; 1 private clinic), 1 rural site (private clinic); 22 providers total). 2) nontraditional HIE-one EMR across multiples sites in an independent practice association (still met investigators definition of HIE); (1 suburban site; private; 16 providers). Patterns included: 1) bulk of info exchanged was related to ordering tests and studies and receiving results from hospitals and independent labs; 2) vital to exchange info with hospitals and specialty practices (consultation reports and discharge summaries).	NR	Family practice sites participating in SNOCAP-USA practice based research network
Ross, *et al.*, 2013[50]	Quality Health Network	Query-based and directed	2005	Claims for 34,818 patients served by 306 providers in 69 practices who had access to the HIE
Rudin, *et al.*, 2009[153]	Massachusetts eHealth Collaborative (MAeHC)	Hybrid HIE	NR	Members of MAeHC collaborative and physician users

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Ross, *et al.*, 2010[167]	Purposeful sampling	Family practice sites participating in SNOCAP-USA practice based research network	None listed	Paper chart only practices and EMR only practices vs. community HIE practices
Ross, *et al.*, 2013[50]	Claims for 34,818 patients	All having access to HIE	None	Rates of laboratory and radiology testing for primary care and specialist care physicians
Rudin, *et al.*, 2009[153]	14 key informants	All interviewed	NA	Technical HIE architecture chosen

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Ross, *et al.*, 2010[167]	-Desired HIE functions -Key motivators -Barriers to and potential incentives for adoption	Practice group	None listed	**Qualitative** Qualitative analysis was iterative, allowing for investigator corroboration, triangulation, and checking; then coding and theming, creation of briefing sheet, then use of modified Delphi method to finalize analysis. Sites also reviewed and corrected reports prior to final report creation.
Ross, *et al.*, 2013[50]	-Rates of laboratory and radiology testing -Economic	Rates of laboratory and radiology testing	None	**Quantitative** Mixed effects regression model
Rudin, *et al.*, 2009[153]	Technical HIE architecture chosen	NA	None	**Qualitative**

Author, Year	Results	Risk of Bias
Ross, *et al.,* 2010[167]	Desired functions of HIE: Universally valued was improved ability to receive and review clinical info from outside the practice; this much more so than improved ability to send or make available info from inside the practice. Paper- and EMR-only anticipated little value in sharing their data with others, but HIE practices realized the value of having their data available anytime/from anywhere. There was consensus that community hospitals and independent lab info would be essential. Also highly desirable to include exchange with specialists. Test results considered most important; followed by discharge summaries. Mean ranking of potential HIE functions (1=highest; 5=lowest rank): looking up info 1.9; delivering results 2.2; e-prescribing 2.5 (lack of computers in exam rooms was a barrier for this one); placing nonprescription orders 3.8; creating reports 4.7; secure email was a lower priority. Essential attributes of HIE: solid reliability and responsive service; live and direct technical support; comprehensive policies and systems for privacy, security and data use Motivations for adopting HIE: motivated to gain uniformity in workflow; improved efficiency (even though did not anticipate monetary benefit; improved quality of care through better coordination and information; Barriers and facilitators: 1) Barrier: technical-need to interface with existing systems 2) Barrier: workflow issues-most sites did not want to re-engineer workflow 3) Best facilitator: technical assistance for implementation & maintenance; and training 4) Barrier: financial issues; secondary, but important; capital costs were barrier; not concerned with loss of revenue 5) Facilitators: solidarity & trust were important (easier in smaller cities); wanted involvement by practice leaders, NOT health plans; neutral about government, foundations 6) Practices thought they could education patients to have trust	Moderate
Ross, *et al.,* 2013[50]	For PCPs, rate of laboratory testing increased over the time span (baseline 1041 tests/1000 patients/quarter, increasing by 13.9 each quarter) and shifted downward with HIE adoption (downward shift of 83, $p<0.01$). For specialist providers (baseline 718 tests/1000 patients/quarter, increasing by 19.1 each quarter, with HIE adoption associated with a downward shift of 119, $p<0.01$). Imputed charges for laboratory tests did not shift downward significantly in either provider group. For radiology testing, HIE adoption was not associated with significant changes in rates or imputed charges in either provider group.	Low
Rudin, *et al.,* 2009[153]	To become established, HIE efforts must foster trust, appeal to strategic interests of the medical community as a whole, and meet stakeholder expectations of benefits from quality measurements and population health interventions.	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Rudin, *et al.,* 2011[136]	Cross-sectional	What affects clinician use of HIE	Massachusetts	Hospitals and physician offices	**Interviews of clinician users and HIE staff**	October 2009-February 2010
Saff, *et al.,* 2010[154]	Cross-sectional	Description of motivation, implementation and use of San Francisco Bay Area HIE	San Francisco Bay Area	5 health organizations; 2,800 MDs; 900,000 patients; numerous labs; several IT vendors	**Database** Varying types of clinical and administrative data - varies by site	Each medical center joined the HIE at a different time, dating from 2002
Schabetsberger, *et al.,* 2006[172]	Prospective cohort	Describe evolution and use of system, problems.	Tyrol, Austria	Tiroler Landeskrankenanstalten, 6 hospital, 6,000 staff, 1,000 physician, 300,000 outpatient, 70,000 inpatient, 400 medical student health system	**Audit logs**	June 2003 and October 2004

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Rudin, *et al.,* 2011[136]	Massachusetts eHealth Collaborative (MAeHC)	All nontext portions of medical record. Could link directly from the EHR to existing HIE. Query-based exchange. Consent was 'opt-in'.	Mid-2007	Clinician users and staff who implemented HIE
Saff, *et al.,* 2010[154]	NR	Each medical center valued the HIE for different reasons; descriptions are provided	NR	900,000 patients in the San Francisco and the East Bay
Schabetsberger, *et al.,* 2006[172]	Various	(1) Discharge summaries push to GP EHRs as text documents, 92+% electronically (2) Standalone web-based archive of hospital documents for nonaffiliated physician access	May 2002-October 2004	Tyrol, Austria physicians

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Rudin, *et al.,* 2011[136]	15 clinicians and 2 HIE staff and 3 administrators	NA	None	None
Saff, *et al.,* 2010[154]	900,000 patients in San Francisco and the East Bay	None specifically stated; all patients included	None specifically stated; all patients included	None
Schabetsberger, *et al.,* 2006[172]	NR	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Rudin, *et al.,* 2011[136]	Motivators and moderators of use	Qualitative	NA	**Qualitative** **C**ontent analysis
Saff, *et al.,* 2010[154]	Lessons learned	Characteristics of each health system; this is a descriptive case study	NA	**Quantitative** Descriptive
Schabetsberger, *et al.,* 2006[172]	System use	NA	NA	**Quantitative** Descriptive

Author, Year	Results	Risk of Bias
Rudin, *et al.,* 2011[136]	-Motivators were belief in improved quality of care, time savings, and reduced need to answer questions. Cost of care was not listed as a motivator. -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. -Patient-related moderators were those who had trouble communicating, multiple comorbid illnesses, and who received care at multiple sites within but not outside HIE. -Clinician-related moderators varied by specialty, use of paper and fax, and integration into workflow. -HIE-related moderators were gaps in data from local nonparticipants, poor usability, and downtimes. -Clinicians varied in how quickly they "locked" data for transfer into HIE.	Low
Saff, *et al.,* 2010[154]	**Lessons learned** -Moved from a competitive to collaborative model -EMR/PHR integration -Extensive testing required to ensure quality of data fit for use -Physician education and engagement required/important	High
Schabetsberger, *et al.,* 2006[172]	-6% to 8% of approximately 40,200 discharge letters were sent out electronically -Problems: corrupt data in physician database; differing implementations of standards (EDIFACT standard); independent, nonfederated patient index; 4 GPs and the psych ward had security concerns	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Schoen, *et al.,* 2012[95]	Cross-sectional	To explore the experiences of physicians in primary care with health reform policies.	Australia, Canada, France, Germany the Netherlands, New Zealand, Norway, Switzerland, The United Kingdom and the U.S.	Primary Care Practices	**Survey responses**	March - July 2012
Shapiro, *et al.,* 2013[51]	Retrospective cohort	Measure incremental increase in number of frequent ED users identified when data from all EDs (using HIE) were compared with use of site-specific data only	New York City	10 hospitals that participated in NYCLIX	**Log file** NYCLIX data (which also included data from site-specific EMRs)	June 1, 2010-May 31, 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Schoen, *et al.,* 2012[95]	NR	Electronic exchange of patient summaries and test results with doctors outside their practice.	NR	General practice and family practice physicians in all countries, as well as general internists and pediatricians in Germany and the U.S.
Shapiro, *et al.,* 2013[51]	10 hospitals that participated in New York Clinical Information Exchange (NYCLIX); NYCLIX is a RHIO in NY City; data sent to NYCLIX by each participant organizations; master patient index links each patient across sites; NYCLIX staff was 'honest broker' and provided data.	New York Clinical Information Exchange (NYCLIX)	NR	All patients with ≥1 instance of ≥4 ED visits within 30 days during study period

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Schoen, *et al.*, 2012[95]	**Primary Care Physicians Surveyed** Australia: 500 Canada: 2,124 France: 501 Germany: 909 The Netherlands: 522 New Zealand: 500 Norway: 869 Switzerland: 1,025 United Kingdom: 500 U.S.: 1,012 Overall: 8,462	Practicing physicians were randomly selected from public and private lists typically used in each country	NR	NR
Shapiro, *et al.*, 2013[51]	924,675 ED visits by 591,632; 920,507 ED visits by 591,632 patients	All patients with ≥1 instance of ≥4 ED visits within 30 days during study period	4,168 visits because they occurred within 6 hours of a previous ED visit, which investigators decided a priori might represent clerical errors	EMR use without accessing HIE

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Schoen, *et al.,* 2012[95]	Ability to electronically exchange patient summaries and test results with doctors outside their practice	NA	NA	**Quantitative** Survey, Chi^2 tests
Shapiro, *et al.,* 2013[51]	-Number ED visits -Number of patients experiencing these visits -Average number ED visits per patient during 12 months -Number patients frequent ED users (per definition) -Number of ED visits accounted for by frequent users -Average number visits per frequent user -Increase in number of frequent users when estimated across HIE (vs. within each site)	-Gender -Age	Cross-over visits (different EDs)	**Quantitative** -Chi^2 -Wilcoxon sign rank test

Author, Year	Results	Risk of Bias
Schoen, *et al.*, 2012[95]	**% of primary care physicians reporting HIE capabilities:** Australia: 27 Canada: 14 France: 39 Germany: 22 The Netherlands: 49 New Zealand: 55 Norway: 45 Switzerland: 49 United Kingdom: 38 U.S.: 31 In the U.S. capacity for electronic exchange of patient information was concentrated in larger practices and those in integrated health systems (50% of physicians reported HIE vs. 23% of physicians not part of integrated practices p<0.05)	High
Shapiro, *et al.*, 2013[51]	Total visits: 924,675 (591,632 unique patients) After exclusion: 920,507 visits by 591,632 patients Mean ED visits/year: 1.6 When used only site-specific data only: 4,786 patients met criteria of frequent user (represented 0.8% of all users) Number of ED visits: 45,771 Mean visits/years: 9.6 (accounted for 5% of ED visits) **HIE-wide results** 5,756 frequent ED users 20% increase in number of frequent user events identified 53,031 visits (6% of all ED visits) Thus HIE data produced 16% increase in number ED visits that could be identified Frequent users more likely to be male: 51% vs. 45%, p<0.0001 Mean age higher: 40.7 vs. 37.9 years, p<0.0001 More had cross-over visits: 28.8% vs. 3%, p<0.0001	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Sicotte and Paré, 2010[168]	Multiple case studies	Describe the implementation and deployment of 2 large HIE projects.	Quebec, Canada	Case 1: 3 pediatric hospitals. Case 2: Primary care network linking a public hospital to 10 private clinics.	**Interviews, observations, documents** 52 interviews (27 for Case 1, 25 for Case 2); all documents from the HIE project team, HIE organizations and vendors; and observations at HIE project meetings	January 2001 + 42 months (Case 1); May 2001 + 32 months (Case 2)
Silvester and Carr, 2009[114]	Before and after	Description of implementation - use of system.	Brisbane & Northern Territories of Australia	239 GPs from 66 practices, 2 major public hospitals, 3 large private hospitals, 11 allied health/ community based partners	**Database** Registration, communication, and clinical database. Clinical database contains socioeconomic status, medications, diagnosis, allergies, medical history, diagnostic results, care team members, unstructured documents	April 30, 2007-July 2008
Soderberg, Laventure, and Minnesota, 2013[90]	Time Series	To monitor progress toward meeting the legislative requirement that all health care providers have an interoperable EHR by 1/2015.	Minnesota	Clinics	**Survey** 72 survey questions	February 15-March 15, 2013

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Sicotte and Paré, 2010[168]	Case 1: 3 pediatric hospitals. Case 2: Primary care network linking a public hospital to 10 private clinics.	Case 1: large pediatric hospital, 2 community pediatric hospital, 4 pediatric clinics. Case 2: public hospital, over 100 physicians at 10 private clinics. Access to laboratory and imaging results.	Specific date unclear	Key informants description limited to HIE project staff and HIE users
Silvester and Carr, 2009[114]	Name NR 239 GPs from 66 practices, 2 major public hospitals, 3 large private hospitals, 11 allied health/community based partners	Software developed by HealthConnect; web services, HL-7 messaging, extracts data from clinician's software package, interfaces seamlessly with clinician's software, uses Medicare Australia's public key infrastructure security certificates for authentication; patients 'opt-in'.	Prior to April 30, 2008; implemented iteratively to ensure success	Registered patients with chronic conditions, cared for at these sites
Soderberg, Laventure, and Minnesota, 2013[90]	Varies	Varies	Varies	1,623 ambulatory clinics

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Sicotte and Paré, 2010[168]	52 interviews (27 for Case 1, 25 for Case 2)	NR	NR	NA
Silvester and Carr, 2009[114]	1,108 patients in population	None, other than stated in population and sample	None, other than stated in population and sample	Before implementation
Soderberg, Laventure, and Minnesota, 2013[90]	The response rate was 79%, with 1,286 clinics responding	Any location where primary or specialty care ambulatory services are provided for a fee by ≥1 physician	NR	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Sicotte and Paré, 2010[168]	Descriptive narrative only	NA	NA	**Qualitative** Empirical observations were organized into narrative using a risk analysis framework
Silvester and Carr, 2009[114]	-Frequency of use (number of events uploaded per patient) -User access logs and patient registration growth rates and connection metrics -User surveys -Patient case studies	None	None	**Mixed methods** -Descriptive summaries -Qualitative analysis
Soderberg, Laventure, and Minnesota, 2013[90]	Exchanges with affiliated and unaffiliated hospitals	NA	NA	**Quantitative** Descriptive statistics

Author, Year	Results	Risk of Bias
Sicotte and Paré, 2010[168]	**Case 1:** 4 stages described: project planning with small part-time team; technical system with risks evolving; testing requiring de-scoping; piloting with user and technical challenges. Overall deliverable not reached, users discouraged and usage was low. **Case 2:** 4 stages described: project planning with full-time staff, system integrator consultant and clinical champions; solicitation of user views and realistic understanding of context, participant contracts signed; system customization and testing, leveraging super-users; piloting, troubleshooting system performance issues. Overall view was successful with high usage.	Low
Silvester and Carr, 2009[114]	-Mean events uploaded for each patient record during 12 months: 9.7 -Increased HIE use by nurses -Number of patients registered increased: 474 (July 2007) to 1,320 (June 2008) -Increased commitment to use -Case studies demonstrated use prevented unplanned inpatient admissions -Interest to adopt by others **Improved staff perceptions in answers to 3 pre-post questions on 5-point Likert scale** Improved understanding of system: 2 to 3 Improved sharing of information: 2 to 2.3 Impact on care delivery: 3 to 3.6 -2 patient-specific case studies showed improved use, communication, satisfaction -Lessons learned included connectivity, interoperability, change management, clinical leadership, targeted patient involvement, information at point-of-care, and governance	High
Soderberg, Laventure, and Minnesota, 2013[90]	-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	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Steward, *et al.,* 2012[169]	Multiple case studies	Understand the dynamic capabilities that enabled the 6 demonstration projects of the Information Technology Networks of Care Initiative to implement HIE.	New York, New Jersey, California, Louisiana, New York	Hospital specialty clinics, support services, primary care clinics, testing sites, ED, outpatient and inpatient clinics, Office of Public Health, insurers, laboratory and pharmacy services	**Interviews** Laboratory, diagnostic, medical, and service utilization; referrals; and ancillary care support, such as case management, counseling and testing, transportation, and substance use and mental health services.	NR explicitly but at 2 points in time: as the HIE were being developed and 1-2 years after the HIE became operational.
Swain, *et al.,* 2015[26]	ONC Data Brief	Summarize trends in HIE use in non-federal acute care hospitals from 2008-2014	NA	NA	Data are from the American Hospital Association (AHA) Information Technology (IT) Supplement to the AHA Annual Survey. Since 2008, ONC has partnered with the AHA to measure the adoption and use of health IT in U.S. hospitals.	2014 update

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Steward, *et al.*, 2012[169]	6 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, NY Presbyterian Hospital, St. Mary Medical Center Foundation	Each of 6 projects implemented a different HIE.	NR	111 project staff and IT specialists; staff from community-based organizations and public health organizations; users of HIE.
Swain, *et al.*, 2015[26]	Varies, as these data are from the AHA survey	Varies, as these data are from the AHA survey	NA	The survey was administered to 4,451 non-federal acute care hospitals, with a response rate of 60%.

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Steward, *et al.*, 2012[169]	NR	NR	NR	Cross-site evaluation
Swain, *et al.*, 2015[26]	The survey was administered to 4,451 non-federal acute care hospitals, with a response rate of 60%.	The survey was administered to 4,451 non-federal acute care hospitals, with a response rate of 60%.	Federal and non-acute care hospitals	prior years

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Steward, *et al.*, 2012[169]	Implementation outcomes	NA	NA	**Qualitative** -Developed 16 coding topics -Convergent and divergent perspectives examined within and across sites
Swain, *et al.*, 2015[26]	HIE use between hospitals and hospitals; HIE use between hospitals and outside providers; Types of data exchanged (Labs, radiology, meds, clinical care summaries)	NA	A logistic regression model was used to predict the propensity of survey response as a function of hospital characteristics, including size, ownership, teaching status, system membership, availability of a cardiac intensive care unit, urban status, and region. Hospital-level weights were derived by the inverse of the predicted propensity.	Estimates considered unreliable had a relative standard error adjusted for finite populations greater than 0.49. Responses with missing values were assigned zero values. Significant differences were tested using $p < 0.05$ as the threshold.

Author, Year	Results	Risk of Bias
Steward, *et al.*, 2012[169]	Found evidence for importance of 3 dynamic capabilities: information systems, reconfiguration capacity, and organization size and human resources. Reconfiguration capacity was most important.	Moderate
Swain, *et al.*, 2015[26]	Hospitals' electronic health information exchange with hospitals or ambulatory care providers outside their organization increased by 85% from 2008 to 2014, and increased by 23% since last year (2013). In 2014, 47 states and the District of Columbia had at least 60% or more of their hospitals electronically exchange key clinical data with outside providers. In contrast, in 2010, 10 states had 60% or more of their hospitals electronically exchange key clinical data with outside providers. In 2014, state rates of hospitals' electronic exchange of key clinical data with outside providers ranged from 42% to 100%; whereas in 2010, hospitals' health information exchange with outside providers ranged from 24% to 67% Approximately two-thirds of hospitals electronically exchanged laboratory results (69%), radiology reports (65%) and clinical care summaries (64%) with outside providers in 2014. Close to six in ten (58%) hospitals exchanged medication history with outside providers. This is an increase of 176% since 2008 and an increase of 57% since 2013. Summary: More than three-quarters (76%) of non-federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with any outside providers. This represents an 85% increase since 2008 and a 23% increase since last year. Close to seven in ten hospitals (69%) electronically exchanged health information with ambulatory providers outside of their organization, representing a 92% increase since 2008 and a 21% increase since 2013.	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Thorn, Carter, and Bailey, 2014[130]	Multiple site case studies	To explore views of emergency physicians having access to HIE, about their access of and use of HIE data	NR	ED in 4 hospitals, private and public settings	**Interviews** Individual unstructured interviews, audio recorded and transcribed	NR
Tripathi, *et al.,* 2009[123]	Multiple case studies	Description of initiative, collaborative design and lessons learned; also includes opt in data by consumer	Massachusetts	3 communities chosen to pilot HIE, Brockton (diverse community), Newburyport (affluent), North Adams (rural)	**Focus groups, documents** Community steering committees, MAeHC, stakeholders; consumer focus groups	Began in 2005 Duration not clear
Tzeel, Lawnicki, and Pemble, 2011[52]	Retrospective cohort	Assess the association of HIE use on health care costs	S.E. Wisconsin (Milwaukee County)	EDs in 5 health systems in a county	**Log file** WHIE data - health plan member with ED encounter when HIE access occurred. Humana claims data - costs and utilization of ED encounter.	December 2008-March 2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Thorn, Carter, and Bailey, 2014[130]	HIE name NR but may be MSeHA Regional HIE operational for 4 years, linking over 450 providers in 15 clinics and 9 major hospitals serving a population of 1 million	Data in HIE NR Decentralized, query-based exchange. Consent was 'opt-out'	NR	ED physicians in 3 urban settings
Tripathi, *et al.,* 2009[123]	Massachusetts eHealth Collaborative (MAeHC)	NR	NR	Number of participants in committees and stakeholders involved not stated
Tzeel, Lawnicki, and Pemble, 2011[52]	Wisconsin Health Information Exchange (WHIE)	Links 5 health systems in the county. Access to patient demographics, chief complaint, allergy, primary care provider, diagnosis, meds, procedures, encounter date & location.	December 2008	Commercial, fully insured members of Humana health plan (denominator); members in the WHIE database having ≥2 ED visits

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Thorn, Carter, and Bailey, 2014[130]	N=15 physicians from 4 urban hospital systems having <10% usage of HIE. Cross section of public and private hospitals. 1 Level I Trauma center. 2 of 4 settings had not implemented EHRs	Full or part-time physicians working regularly scheduled ED shifts. Purposeful selection of 2 because of a 4-year history of HIE use. Rest recruited with "theoretical sampling"	NR	NA
Tripathi, *et al.*, 2009[123]	NA	NA	NA	NA
Tzeel, Lawnicki, and Pemble, 2011[52]	Test group: 428 members with ED visits having an HIE query Control group: 1,054 members with ED visits with no HIE query. Propensity score matching for test group (N=326) with HIE database query in all ED visits vs. control group (N=325) with HIE database not queried in any ED visit.	≥1 year continuous insurance coverage with health plan	<6 months coverage before program started or <3 months after start of program	Pairs matched for age, gender, and costs for net care per participant per month prescriptions, inpatient, outpatient, ED, and physician.

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Thorn, Carter, and Bailey, 2014[130]	Descriptive narrative only	NA	NA	**Qualitative** Thematic, constant comparative analysis of narrative
Tripathi, *et al.,* 2009[123]	-Descriptive narrative only -Type of patient consent -Type of data to share	NA	NA	**Qualitative**
Tzeel, Lawnicki, and Pemble, 2011[52]	-Comparison of net costs and ED costs per participant -Comparison of top 5 ED procedures in test group vs. matched control 1 year before and 1 year after the first ED visit	Pairs matched for age, gender, and costs for net care per participant per month prescriptions, inpatient, outpatient, ED, and physician	NR	**Quantitative** Matched pairs t-tests

Author, Year	Results	Risk of Bias
Thorn, Carter, and Bailey, 2014[130]	**Themes** -Users varied in their HIE use. Stated influencers including trouble accessing system, acuity of patient or history not available, team members' ability to access. -HIE use affected decisions sometimes, for specific cases (e.g. drug seekers); often HIE use did not affect decisions -Use was negatively affected by 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. -Benefits with usage included reducing redundant testing, more accurate history, reducing faxing, knowledge of primary care provider name -Barriers to usage included continued practice of defensive medicine, desire for autonomy, changing the culture, belief HIE does not alter decisions, health system competition, and reduced revenue, workflow disruption.	Low
Tripathi, *et al.,* 2009[123]	**Discussion of experience/lessons learned** -Decision on consent: opt in chosen due to state law stricter than federal HIPAA law; use of a centralized data repository; and consumer feedback. -Data shared: 3 communities agreed on what to share - all EHR except text notes, consult letters and scanned reports. -Consumer focus groups identified themes to drive HIE/opt in: promote convenience and costs, promote with providers, say benefits up front, confront risks, use professional marketing -Consumer opt In across 2 smaller communities: 88% and 92%	NA
Tzeel, Lawnicki, and Pemble, 2011[52]	**Unadjusted:** ED costs in test group changed $1,068 to $999 from 1st to subsequent visit vs. control group changed $1,043 to $1,157 **Adjusted for propensity matching:** Net costs (per participant per month) in test patients with higher net costs overall in and subcategories ED costs: $29 less in test patients from first visit vs. subsequent visits. Top ED procedures: 4 of 5 were reduced in test group (lab, radiology, CT, EKG)	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Tzeel, Lawnicki, and Pemble, 2012[53]	Retrospective cohort	Assess the association of HIE use on hospital admissions	S.E. Wisconsin (Milwaukee County)	EDs in 5 health systems in a county	**Log file** WHIE data - health plan member with ED encounter when HIE access occurred. Humana claims data - costs and utilization of ED encounter.	December 2008-March 2010
Unertl, *et al.,* 2013[170]	Multiple case studies	To investigate how technology and health system coevolve to reduce information fragmentation and improve care coordination (Extension of Unertl 2012 study)	Memphis, Tennessee region	6 EDs and 8 ambulatory clinics	Interviews, observations Direct observation at 14 sites, informal interviews at sites, 9 semi structured telephone interviews	January-August 2009
Unertl, Johnson, and Lorenzi, 2012[119]	Multiple site case studies	To understand the interaction between HIE and workflow. How have sites integrated HIE into existing approaches? Are there common HIE workflow patterns across sites? How do providers incorporate HIE into clinical practice?	Memphis, Tennessee region	6 EDs and 8 ambulatory clinics	**Observations, interviews** Direct observation (180 hours) at 14 sites, informal interviews at sites, 9 semi structured telephone interviews with physicians, nurses and IT management	January-August 2009

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Tzeel, Lawnicki, and Pemble, 2012[53]	Wisconsin Health Information Exchange (WHIE)	Links 5 health systems in the county. Access to patient demographics, chief complaint, allergy, primary care provider, diagnosis, meds, procedures, encounter date & location.	December 2008	Commercial, fully insured members of Humana health plan (denominator); Members in the WHIE database having at least 2 Emergency Dept. (numerator) was the study population.
Unertl, *et al.,* 2013[170]	MidSouth eHealth Alliance (MSeHA), regional HIE around Memphis includes majority of large hospitals and 2 safety net clinic systems.	HIE structure from Vanderbilt University. Data on >1 million patients includes test results, imaging, discharge summaries, diagnosis codes and claims data. Opt out model.	2004	NR
Unertl, Johnson, and Lorenzi, 2012[119]	MidSouth eHealth Alliance (MSeHA), regional HIE around Memphis includes majority of large hospitals and 2 safety net clinic systems.	HIE structure from Vanderbilt University. Consolidated data from multiple hospital emergency departments and community-based ambulatory clinics. Decentralized, query-based exchange. Data on >1 million patients includes test results, imaging, discharge summaries, diagnosis codes and claims data. Opt out model.	2004	NR

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Tzeel, Lawnicki, and Pemble, 2012[53]	Test group: 428 members with ED visits having an HIE query Control group: 1,054 members with ED visits with no HIE query Matched pairs: 325	≥1 year continuous insurance coverage with health plan	<6 months coverage before program started or <3 months after start of program	Pairs matched for age, gender, and costs for net care per patient per month, prescriptions, inpatient, outpatient, ED, and physician.
Unertl, *et al.,* 2013[170]	NA	NR	NR	NA
Unertl, Johnson, and Lorenzi, 2012[119]	NA	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Tzeel, Lawnicki, and Pemble, 2012[53]	-Admissions per 1,000 members, at time of ED visit (1st, 2nd visit) -Conditional probability of admission at ED visit (1st, 2nd) -Bed days per 1,000 members -Average length of stay	Pairs matched for age, gender, and costs for net care per patient per month, prescriptions, inpatient, outpatient, ED, and physician	NR	**Quantitative** Chi^2
Unertl, *et al.,* 2013[170]	Descriptive narrative only	NA	NA	**Qualitative** Open-ended grounded theory analysis, followed by the application of the Information Ecology Framework to structure additional analysis
Unertl, Johnson, and Lorenzi, 2012[119]	Descriptive narrative only	NA	NA	**Qualitative** Grounded method using open coding, and framework-focused axial coding.

Author, Year	Results	Risk of Bias
Tzeel, Lawnicki, and Pemble, 2012[53]	**Adjusted for propensity matching** Admission/1,000 members (1st to 2nd ED visit): 269 to 664 for test group vs. 321 to 555 for control group Probability of admission higher at 1st ED visit in control group, and higher at 2nd ED visit in test group Test group had 771 fewer bed days/1,000 members and lower length of stay than control group Post–propensity matching analysis showed that test group had 199 more admissions per 1000 members than control group, these admissions might have been more appropriate. Test group admissions resulted in less time spent as inpatients and by average length of stay (4.27 days per admission for all admissions and 0.95 days per admission when catastrophic cases removed).	Low
Unertl, *et al.*, 2013[170]	-All sites had coexisting use of HIE and manual processes to access information -Observations were used to map 5 Info Ecology Framework components to a newly developed "Regional Health Information Ecology": 1. system - HIE to reduce information silos; 2. locality - sites had distinct local context; 3. diversity - staff had varied roles with varied HIE processes; 4. keystone species - info consumers, who used data for varied reasons; info reservoirs, people who played formal and informal roles; exchange facilitators, who assisted others and bridged gap between consumers and reservoirs. -Paradox observed: providers describe HIE useful, regardless of use frequency ('when we use it, it's great"); but, provider belief that HIE not being used to full potential. -Examples of impact were identified using their model: a. reduce fragmentation of information; b. reduce time to obtain information; c. increase provider awareness of patient-health system interactions (e.g., drug seeking)	Low
Unertl, Johnson, and Lorenzi, 2012[119]	**Cross organizational patterns; 2 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	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Vest and Jasperson, 2012[103]	Case control	How does HIE access vary by job type and organization in an indigent care HIE in central Texas?	Austin, Texas	Indigent patients and facilities that care for them	Log files from clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, public and private clinics, government agencies (federally qualified health centers)	January 2006-June 2009
Vest, 2009[54]	Retrospective cohort	Test the hypotheses that HIE information access reduced ED visits and inpatient hospitalizations for ambulatory care sensitive conditions among medically indigent adults.	Central Texas	18 members in HIE (I-Care): hospital systems, public and private clinics, and governmental agencies operating federally qualified health centers	**Log file** Demographic, clinical information, diagnoses, medication orders, prior visits, payer sources for uninsured patients.	January 1, 2005-June 30, 2007

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Vest and Jasperson, 2012[103]	Integrated Care Collaboration (ICC)	Clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, clinics, government agencies (federally qualified health centers)	HIE 1997; I-Care database 2002, 3.1 million encounters, 600,000 individuals	Indigent people, not Medicare
Vest, 2009[54]	18 members in HIE: hospital systems, public and private clinics, and governmental agencies operating federally qualified health centers	Each site contributes patient electronic data to I-Care through secure electronic interfaces. In turn, each location may access data from I-Care at a secured website.	HIE 1997; I-Care database 2002, 3.1 million encounters, 600 thousand individuals	Uninsured 18 to 64 years old and excluded encounters at the public mental health provider and Planned Parenthood

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Vest and Jasperson, 2012[103]	105,705 unique user sessions	User session as all system viewing activity (i.e., screens accessed) by a given user for a given patient on a given date.	Could not classify 35 user sessions (0.03%) and excluded them as too few for meaningful analysis.	None
Vest, 2009[54]	3463 HIE access, 2651 No access; 6,114 included out of 600,000 individuals, 3.1 million encounters	Uninsured 18 to 64 years old	Encounters at the public mental health provider and Planned Parenthood. Also excluded encounters related to accidents, pregnancy, labor and delivery.	Persons with no information accessed in the HIE vs. those with accessed information

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Vest and Jasperson, 2012[103]	Administrative vs. clinical vs. repetitive vs. mixed use	-User types and unique job titles -Workplaces	Same day, within a week, within a month, within a year, longer than a year, or no encounter	Cross tabulation to compare usage categories with A) job categories, B) workplace categories, and C) timing of usage categories. Associations evaluated between types of usage and these variables using the Pearson chi^2 test of independence
Vest, 2009[54]	-ED visits and inpatient hospitalizations due to ambulatory care sensitive hospitalizations -Logs document the user's location, the patient viewed, the date accessed, and information screen viewed	-Predictors of HIE use (e.g., demographics, number of chronic conditions, prior ED visits or hospitalizations) -HIE for predicting ED and hospitalizations	-Clinical, demographic, comorbidity, service measures -Created a chronic condition index by summing chronic conditions (diabetes, hypertension, asthma, ischemic heart disease, hypercholesterolemia and stroke)	**Quantitative** -Frequencies and percent -Multiple logistic regression adjusting for confounders

Author, Year	Results	Risk of Bias
Vest and Jasperson, 2012[103]	->6/10 sessions users accessed the system in a minimal fashion -Average pattern length: 2.89 screens -Shortest pattern length included only 1 screen and the longest pattern involved 83 screens -65.7% of all user sessions had a pattern length of only 2 screens -Use was overwhelmingly (93.9%) administrative, roughly evenly distributed across workplaces but for dominance of hospital accesses (37.6%) and about half same day, a fifth first week, a fifth over the year, 1/10 unassociated with encounter; usage type associated with job category: admin, nurse, pharmacy, physician, public/mental health, social services; most clinical access in ED, and public/mental health -297 users, 113 unique job titles, collapsed into administration (59% of users), nurse (~6% of users), pharmacy (~1% of users), physician (~12% of users), public health (~6% of users), and social services (~15% 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.	Low
Vest, 2009[54]	**Adjusted OR of HIE information access** Increasing age: 1.03; number of chronic conditions: 1.13; ≥1 prior year clinic visit: 1.63; a prior year ED visit: 1.96; and being hospitalized in 2004: 2.02 All levels of HIE information access were associated with increased expected ED visits and ambulatory care sensitive hospitalizations vs. no information access -HIE was used more for those that used the system more, or were sicker. -HIE was not accessed for 43% of individuals -Ultimately, these results imply that HIE information access did not transform care in the ways many would expect. Expectations in utilization reductions, however logical, may have to be reevaluated or postponed. -Patients with HIE information accessed one time had an 83% higher expected count of ED visits.	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Vest, 2010[155]	Cross-sectional	Which nontechnological and technological factors may still hamper the existence of effective HIE even in light of the substantial financial incentives offered via the HITECH Act?	U.S.	U.S. Hospitals	**Surveys** 2008-2009 HIMSS Analytic Database; AHA Annual Survey 2007	After 2009
Vest and Miller 2011[64]	Retrospective cohort	Do hospitals using HIE have higher reported communication among health professionals and/or higher patient satisfaction?	U.S.	Hospitals	**Log file** -2008-2009 HIMSS Analytic Database -AHA Annual Survey 2007 -Review of all HIE facilitating efforts in U.S., linked to HCAHPS survey	After 2009
Vest, *et al.,* 2011[105]	Case control	Do hospitalizations, ED visits, and other factors predict HIE use for indigent adults?	Austin, Texas	Indigent patients and facilities that care for them	Log files from clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, clinics, government agencies (federally qualified health centers)	January 2006-June 2009

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Vest, 2010[155]	Various	Various	Various	U.S.
Vest and Miller 2011[64]	Various	Various	Various	U.S
Vest, *et al.,* 2011[105]	Integrated Care Collaboration (ICC)	Clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, public and private clinics, government agencies (federally qualified health centers)	HIE 1997; I-Care database 2002, 3.1 million encounters, 600,000 individuals	Indigent people, not Medicare

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Vest, 2010[155]	4,830 hospitals in AHA and HIMSS-AD	In AHA or HIMSS survey	NR	Operational vs. adopted not operational vs. not adopted
Vest and Miller 2011[64]	3,278 hospitals, 340 adopted, 351 implemented HIE	Participated in AHA or HIMSS survey	Too few observations (HCAHPS survey responses <100)	Adopted vs. implemented vs. none
Vest, *et al.,* 2011[105]	271,305 encounters (111,482 unique patients) from 10 facilities; (Vest 2009 was 3,463 HIE access, 2,651 no access; 6,114 included out of 600,000 individuals, 3.1 million encounters)	All ED encounters among patients ages 18 to 64 that occurred between January 1, 2006 and June 30, 2009	Excluded any ED encounters occurring at facilities before the hospital had an authorized user of the I-Care system.	None

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Vest, 2010[155]	HIE adoption (operational, implementing, nonadapter)	Technological readiness (number of live applications, CCHIT EMR), vertical integration, horizontal integration, high/low information needs, inpatient admissions, market competition, uncompensated care burden, primary care rate, health system/network size	-Classic markers of innovation adoption considered covariates -Total number of beds (size) -Average days cash on hand from all sources -Nonmetropolitan location -General innovativeness was measured both as academic affiliation and specialization, the standardized total number of professional job categories	**Quantitative multivariate analysis** -Begins with, or assumes, TOE framework: technological, organizational, and environmental; missing values imputed from earlier versions of AHA Guide and HIMSS-AD -Logistic regression on adoption, logistic regression on operational
Vest and Miller 2011[64]	-Percentage of patients who reported their doctors and their nurses always communicated well -Percentage of patients who would definitely recommend the hospital -Percentage of patients who gave the hospital a high global rating (≥9 on a 10-point scale)	Level of HIE participation: implemented (active sharing); adopted (participating but not yet sharing); or none	Organizational variables associated with HCAHPS outcomes; other AHA organizational characteristics, overall level of automation in hospital, external factors such as state regulations	**Quantitative** -Least squares regression -Propensity score adjustment
Vest, *et al.,* 2011[105]	No usage vs. basic usage vs. novel usage (more screens)	-Familiarity -Complexity -Mental/substance use -Frequency of prior utilization elsewhere -Time constraints	Assessed with multivariate analysis, otherwise NR	**Quantitative multivariate** Logistic regression with adjustment for by-patient clustering

Author, Year	Results	Risk of Bias
Vest, 2010[155]	-59 operational and 123 nonoperational exchanges -453 hospitals operational HIE, 446 adopted HIE, and 3,931 had not adopted HIE; sample includes more general service type and fewer for-profit hospitals than the more nationally representative AHA survey -Overall, 81.4% of hospitals had not adopted or implemented HIE -Adjusted regression OR of adoption for not for profit: 8.57; public: 9.53; number operational application: 1.02; physician portals: 1.38; network membership: 1.33; ED visit: 1.01' primary care MD in HRR: 1.03 -Adjusted regression OR of implementation: network membership: 1.96; hi competition: 0.15; primary care MD: NS	Low
Vest and Miller 2011[64]	-10.4% had adopted -10.7% had implemented HIE -Implemented hospitals, but not adopted hospitals, had higher nurse communication (0.75 increase [95% CI, 0.13 to 1.38]), global satisfaction (0.82 [95% CI, 0.01 to 1.64]), and would recommend scores (1.34 [95% CI, 0.41 to 2.27]), and a trend toward higher doctor communication scores (NS after controlling for confounders); results attenuated in propensity score analysis -Communication: higher for smaller hospitals, rural hospitals, fewer Medicaid patients, higher nurse/patient ratios -Satisfaction: higher for nonprofit, smaller, Midwest or south, fewer Medicaid patients, higher nursing ratios	Low
Vest, *et al.,* 2011[105]	-No access of system for 97.7% of encounters -Users accessed the I-Care system for 2.3% of the 271,305 encounters -Basic usage (2,527) 41.1% of instances -Sample was predominately Hispanic, younger, and a higher proportion of charity care recipients -Adjusted OR of access for African American and Hispanic: 0.76 to 0.89; higher for unknown or charity care; but mainly for unknown payer: 4.7 vs. 2.6; access higher for more ED visits; hospitalizations: ~1.25-1.5 (from graph) -Access lower for alcohol use, injury, poisoning, unfamiliar patient, busier than average day	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Vest, *et al.,* 2011[104]	Case control	Do hospitalizations, ED visits, and other factors predict HIE use for indigent children?	Austin, Texas	Indigent patients and facilities that care for them	Log files from clinical data repository (Indigent Care Collaboration of Austin, Texas safety net providers founded 1997); 18 hospitals, clinics, government agencies (federally qualified health centers)	January 2006-June 2009
Vest, *et al.,* 2012[103]	Case control	Use of HIE in 2 ambulatory indigent clinics without EHRs, and patient factors associated with this use.	Austin, Texas	2 ambulatory clinics serving indigent people, part of nonprofit hospital system, 10,550-12,250 encounters/year	Log files from clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, public and private clinics, government agencies (federally qualified health centers)	January 2006-June 2009
Vest, Campion Jr., and Kaushal, 2013[156]	Cross-sectional	Identify the strengths and weaknesses of organizational models to achieve exchange, and what can be done to ensure the sustainability and effectiveness o	New York State	HEAL-NY (HIE promotion legislation), HITEC (academic collaborative performs evaluations)	**Interviews** Semi structured interviews with selected experts	March - June 2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Vest, *et al.,* 2011[104]	Integrated Care Collaboration (ICC)	Clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, clinics, government agencies (federally qualified health centers)	HIE 1997; I-Care database 2002, 3.1 million encounters, 600,000 individuals	Indigent people, not Medicare
Vest, *et al.,* 2012[103]	Integrated Care Collaboration (ICC)	Clinical data repository (Indigent Care Collaboration of Austin, Texas safety network providers founded 1997); 18 hospitals, clinics, government agencies (federally qualified health centers)	HIE 1997; I-Care database 2002, 3.1 million encounters, 600,000 individuals	Indigent people, not Medicare
Vest, Campion Jr., and Kaushal, 2013[156]	Various	Various	Various	New York State

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Vest, *et al.,* 2011[104]	179,445 encounters	All ED encounters among patients <18 years occurred between January 1, 2006 and June 30, 2009 and had parental consent	Excluded any ED encounters occurring at facilities before the hospital had an authorized user of the I-Care system.	None
Vest, *et al.,* 2012[103]	39,447 encounters 6,393 patients	Age 19-64 years Austin metro area, consent to inclusion	Children (different utilization) or ≥65 years (Medicare)	None
Vest, Campion Jr., and Kaushal, 2013[156]	17 of 21 invited HIE experts	Selected to represent public, private, leaders, participators, policymakers	None stated	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Vest, *et al.,* 2011[104]	No usage vs. basic usage vs. novel usage (more screens)	3 factors as indicative of uncertainty that creates an information need: comorbidity, prior utilization, and unfamiliarity with the patient	NR	**Quantitative multivariate** Logistic regression with adjustment for by-patient clustering
Vest, *et al.,* 2012[103]	Encounter level or retrospective usage	-Age -Gender -Race -ED visits over 3 months -Hospitalization over 12 months -Fragmentation (N of clinics -1) -Payer (Medicaid or not) -Charlson comorbidity -Independent mental health/substance abuse comorbidity -AHRQ chronic conditions indicator definitions	Assessed with multivariate analysis, otherwise NR	**Quantitative multivariate** Primary care encounter: unit of analysis; multinomial regression, clustered to account of unit of analysis, adjusted for confounders
Vest, Campion Jr., and Kaushal, 2013[156]	NA	NA	NA	**Qualitative** Semistructured interview exploring issues from literature, open independent coding and comparison by 2 investigators, consensus; [no triangulation of data or analysis, no member check]

Author, Year	Results	Risk of Bias
Vest, *et al.,* 2011[104]	-System accessed: 15,586 of 179,445 encounters (8.7%) -OR of basic HIE access for >1 year old vs. ≤1 year old: ~1.5 (from graph); lower for race unknown; higher for payer unknown; PC visits within 12 months: ~1.5 (from graph); ED visits within 12 months: 1.5-2 (from graph); hospitalized: 1.3; number of diagnoses: 1.05; unfamiliar: 0.46; busier than average: 0.65 -OR of novel HIE access for >1 year old vs. ≤1 year old: ~1.3; NS for race unknown; higher for payer unknown; PC visits within 12 months: ~2 (from graph); NS for ED visits within 12 months; hospitalized: 1.15; number of diagnoses: 1.05; unfamiliar: 0.19; NS busier than average	Low
Vest, *et al.,* 2012[103]	-Access for 21% of encounters -7,101 encounter based, 1,227 retrospective -Adjusted OR for association with access for female: 1.12; >40 years: 1.16; chronic disease: 1.19; ED visit last 3 months: 1.13; -Retrospective access, same 4 factors plus hospitalized last 4 months OR 1.33 and fragmentation OR 1.52	Low
Vest, Campion Jr., and Kaushal, 2013[156]	Themes: **(A) HIE is a public good; (B) challenges** (1) financial challenges include upfront costs, discordance between investors and beneficiaries of technology "how to make that savings accrue to us and not to the payers."; opportunity cost of lost revenue and lack of ROI "from a business perspective, HIE is kind of a bad idea. Why would we send out patient information elsewhere? We want to do it, we think it's necessary for better care of the patient, but we'll lose money by doing it."" (2) governance because "Federal, state, and private representatives were fairly unanimous in their opinions that the functioning of RHIOs was not a technical issue" and the necessity of trust; (3) mismatch of geographical model with reality of large integrated multistate delivery systems; **(C) alternative**s include Direct (lightweight, treatment focused, lower organizational overhead; enterprise RHIOs, e.g.. "he hospital systems, they are the RHIO and they don't want to play with anybody else because they basically have quasi monopolies and cartels." and don't need outside connection or support; Vendor models likely but suboptimal; any of these not c/w state intent; **(D) Sustainability** quixotic, aims are contrary to market, contradiction of " tension between providing a public good with little market incentives and operating like a private business"; alternatives: grow exchange effort, specify a focus, evolve as an organization	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Vest, *et al.,* 2013[102]	Case control	Display and analyze the pattern of radiology report requests among organizations participating in an HIE, and identify the patient and provider factors associated with use of a HIE system to access radiology report	Western New York State	Nonprofit RHIO working with Hospital systems, reference laboratories, radiology groups, insurance providers, and county offices	Log files, RHIO information about job title, job type, and location, and claims data.	The log file was limited to patients 18 years and older and reflected patient encounters from January 2009-March 2011
Vest, *et al.,* 2014[56]	Retrospective cohort	Examines the hypothesis that usage of an HIE system reduces the odds that a patient in the ED will be hospitalized.	Rochester, New York	HEAL NY legislation, statewide HIE initiatives	**Log file** Claims files from 2 health plans that insure more than 60% of the area population, log files of usage, RHIO roster of users	2009-2010

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Vest, *et al.*, 2013[102]	Rochester RHIO	Commercial query-based web portal product, which includes patients' discharge summaries, prior diagnoses, radiology reports, medication history, and payer information. Both radiology reports and images are accessible within the HIE system and are typically available in near-real time after signoff. Imaging studies are accessible only if the user first views the radiology report. Our analysis is limited to the viewing of reports only.	NR	Patients in health system in western New York
Vest, *et al.*, 2014[56]	Rochester RHIO	>70 organizations in 13 county regions of western New York. Web-based portal that includes discharge summaries, diagnoses, radiology reports and images, medication history, and payer information	Fully operational in March 2009	1,318 users accessed patient records in 156 different outpatient, emergency, inpatient, long-term care, and specialty care settings via a web portal. 7 EDs were included; 800,000 patients (>70% of the area's adult population)

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Vest, *et al.,* 2013[102]	29,528 radiology documents originating at 17 different source organizations, including hospitals and radiology practices. A total of 126 different practice locations viewed these documents.	Claims data only covers 60% of population, included consenting patients with ≥1 encounter in 6 months after consent	<18 years, not in health system (included 60% of pop, not the other 40%), had claims (64%, not the other 36%)	NA
Vest, *et al.,* 2014[56]	1,5645	Claims files for 65% of patients ≥18 years with valid consent dates (n=198,067) who had ≥1 encounter with a provider registered to use the HIE system in the 6 months following their consent date.	None reported	HIE access vs. no HIE access (from log files)

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Vest, *et al.,* 2013[102]	Radiology report access	-Demographics -Encounter history -User characteristics -Insurance type -AHRQ CCS ICD-9 codes -Use of services in 30 days prior to access -Claims for imaging procedures -Health professional encounters	NR	**Quantitative multivariate** Using network/graph analysis assessed the difference between the average number of connections among sources vs. user practice locations, as well as the average number of radiology documents exchanged by data sources vs. data users. Then (2) mixed effects logistic regression on 134,127 sessions, 64% linked to claims files, with some accounting for clustering by patient, user, workplace - report results without control for confounders, multiple comparisons problem
Vest, *et al.,* 2014[56]	Hospital admission via the ED Economic	HIE system use at the time of the ED visit, measured in a yes/no fashion	-Gender -Age -Payer -Disease severity in the 12-month period -Any primary care, specialty care, or ED visits in the 30 days after the index hospitalization (or up until the date of readmission)	**Quantitative** Logistic regression models. The full model adjusts for all independent variables with patient age, the count of major aggregated diagnostic groups, and the number of prior hospitalizations treated as continuous variables, 4 sensitivity analyses to explore the robustness including physician effects and patient subgroup (sickest) effects

Author, Year	Results	Risk of Bias
Vest, *et al.*, 2013[102]	**Network:** each source organization sent on average 971 (range: 6-8,002) documents to 49 (3-106) other organizations. User organizations accessed on average 49 (1-8,444) documents from 6 (1-17) source organizations. Algorithm suggests 11/17 source organizations represent a core set of data providers, including 8 hospitals and 3 stand-alone radiology sites. Thus the overall number of radiology reports retrieved in the outpatient setting was 16.9 times greater than the number of reports retrieved in the ED and inpatient settings combined (23,201 outpatients vs. 1,333 ED and 313 inpatients). **Factors:** 86,152 user sessions with associated claims files represented the activity of 1,119 different users representing 145 different workplace locations. 86.4% were staff; physicians represented only about 4% of all sessions; overall 11.2% of sessions included access of radiology reports.	Low
Vest, *et al.*, 2014[56]	-ED visit within 6 months of consent: 15,645 -Of ED visits, HIE accessed: 2.4% (n=374) -16/229 MDs used system -OR of admission for Medicare: 2.02; Medicaid: 0.61; male: 1.47 -Adjusted OR of HIE access: 0.7; HIE access on same day as ED visit: 0.83 (95% CI, 0.55 to 1.25) -Odds of an admission were 30% lower when the system was accessed after controlling for confounding (OR 0.70; 95% CI, 0.52 to 0.95) -Annual savings in the sample was $357,000	Low

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Vest and Issel, 2014[157]	Cross-Sectional	To examine factors related to public health organizations data exchange capabilities	United States	State and local health departments	Surveys	2007-2008
Vest, *et al.,* 2014[55]	Retrospective cohort	To determine the association between usage of an HIE system post- discharge and 30-day same-cause hospital readmissions.	Rochester, New York	HEAL NY legislation, statewide HIE initiatives. Outpatient	**Log file** Claims files from 2 health plans that insure more than 60% of the area population, log files of usage, RHIO roster of users	2009-2010
Willis, *et al.,* 2013[67]	RCT	To evaluate 2 decision support interventions: patient adherence reports to providers and reports to providers and emails to care managers by comparing to usual care.	North Carolina	Outpatient	**Database** EHR and claims as well as logs of contacts and cost/revenue data	-December 7, 2009-December 6, 2010 was intervention period -Followup for outcomes ended August 30, 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Vest and Issel, 2014[157]	Varies, any system that would allow data sharing	Varies	Varies	U.S. states
Vest, *et al.,* 2014[55]	Rochester RHIO	Web based portal that includes discharge summaries, diagnoses, radiology reports and images, medication history, and payer information, 38 healthcare organizations in 11 counties	Fully operational in March 2009	800 000 patients (>70% of the area's adult population)
Willis, *et al.,* 2013[67]	Northern Piedmont Community Care Network. Set up a system called COACH (Community-Oriented Approach to Coordinated Healthcare)	-Included 9 clinics and 5 hospitals -Data collected by the system include: 1) administrative data 2) care management data; 3) claims/billing data ; 4) scheduling data; 5) clinical data; 6) data on communications	NR	Network Medicaid beneficiaries

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Vest and Issel, 2014[157]	44 states with representatives who responded to both surveys	Executive officer of local health department and state health officials	States missing data on either survey	Public health organizations that don't have the capacity to exchange data
Vest, *et al.*, 2014[55]	196,314 patients, 11 hospitals (2/3 of sample)	≥18 years, consented during 2009-2010, continuously enrolled in health plan, ≥1 encounter in 6 months following consent, (196,314 patients met these requirements). Only the patient's first hospital admission within the first 5 months after consent. Each patient appears in the dataset only once and each discharge could be followed for ≥30 days.	<30 observations in the dataset (n=11)	HIE access vs. no HIE access (from log files)
Willis, *et al.*, 2013[67]	N=2219 739 to usual care 744 clinic reports 735 clinic reports and care manager notices	Patients with ≥1 of 6 targeted IOM priority conditions	Not continuously enrolled during the intervention period	Provider report vs. provider report and case manager event vs. usual care in which neither type of alert was delivered

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Vest and Issel, 2014[157]	Bidirectional data sharing for childhood immunizations, vital records and reportable conditions	Organizational characteristics including size, structure, processes and IT readiness	None reported	Quantitative Multivariate Analysis
Vest, *et al.,* 2014[55]	Readmission within 30 days of discharge for the same cause as the index hospitalization	HIE system usage	-Gender -Age -Payer -Disease severity in the 12-month period any primary care, specialty care, or ED visits in the 30 days after the index hospitalization (or up until the date of readmission) -Described the index hospitalization site: hospital bed size, teaching status, affiliation with a multi-hospital healthcare system, and critical access hospital classification, case mix index derived from the relative values of diagnosis-related groups seen at the hospital	**Quantitative** Random effects logistic regression models, a series of models adjusting for patient characteristics, then adding post-discharge utilization measures, and lastly including hospital-level characteristics. Controlled for potential hospital-level clustering using the index admission hospital as a random intercept. Then 2 sensitivity analyses.
Willis, *et al.,* 2013[67]	-Clinical outcomes including: medical adherence, outpatient, ED visits, and hospitalizations -Care coordination costs/revenues -Clinician satisfaction	Group assignment	None reported	**Quantitative** Generalized estimating equation models that accounted for clustering by family

Author, Year	Results	Risk of Bias
Vest and Issel, 2014[157]	Data sharing capacity varied by activity. 66% had capacity for Immunizations 30.2% for vital records and 18.9% for reportable conditions	Moderate
Vest, *et al.*, 2014[55]	-Readmitted within 30 days: 9.8% (668/6,807); 29.6% at a different facility; 394 had HIE access within 30 days after discharge, 20 (5.8%) readmitted; p=0.00113 -ED visits within 30 days post discharge: NS -HIE access associated with lower readmissions: OR 0.43 (95% CI, 0.27 to 0.70) -Primary care or specialty care associated with lower readmissions rates: ORs 0.48 and 0.67 in final model -ED visits associated with higher rates: OR 9.3 in final model -Accessing patient information in the HIE in the 30 days after discharge associated with a 57% lower adjusted odds of readmission (OR 0.43; 95% CI 0.27 to 0.70). Estimated annual savings in the sample from averted readmissions associated with HIE usage was $605,000.	Low
Willis, *et al.*, 2013[67]	**Control vs. reports vs. reports and email** % medication adherence: 41.3% vs. 41.2% vs. 42.9%, p=NS; no differences between groups at 6 months Encounter rates of outpatient: 46.0 vs. 46.6 vs. 44.5, p=NS Encounter rates of ED: 0.87 vs. 0.84 vs. 0.89, p=NS Encounter rates of hospitalizations: 0.19 vs. 0.21 vs. 0.21, p=NS -15% to 50% of reports were not available to providers at time of patient encounter -Even when they had reports, clinicians did not always discussion medication adherence with patients	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
Winden, *et al.,* 2014[71]	Case series	To determine value of Epic Care Everywhere in an ED	Minneapolis, Minnesota	ED	**Observations** Chart review, focus groups, survey	January-November, 2012
Yeager, *et al.,* 2014[137]	Cross-sectional	To examine the barriers and facilitators affecting the decision to participate in an HIE and, separately, which factors are affecting the use of HIE.	Louisiana	NR in this paper	**Interview**	March to April 2013

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
Winden, *et al.,* 2014[71]	Allina Health and local organizations using Epic	Directed transfer of Epic records to Allina ED	August, 2010	All patients for whom CE used; focus groups of clinician users
Yeager, *et al.,* 2014[137]	Louisiana HIE (LaHIE), statewide. Number of centers/settings not presented in this paper.	Louisiana HIE (LaHIE). LaHIE functions as a hybrid centralized and federated model, web-based platform for providers to share patient care continuity documents (commonly referred to as CCDs), laboratory results, and electrocardiogram results.	NR	Patients in Louisiana

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
Winden, *et al.,* 2014[71]	Focus groups: 49 clinicians in 4 hospitals; Survey: 118 of 408 ED staff; review of 1,488 notes where CE used	Focus groups: clinicians; Survey: ancillary staff; Notes: use of CE	Notes: CE not used	Focus group and survey: value for care; Chart review: tests avoided
Yeager, *et al.,* 2014[137]	16 Healthcare representatives from organizations interested in joining LaHIE but not yet enrolled (n=4), not interested in joining (n=4), or already enrolled (n=8)	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
Winden, *et al.,* 2014[71]	Focus groups: provided value for patient care, especially for avoiding duplicate testing and detecting drug-seeking behavior; Survey: provided value in patient care; Chart review: procedures avoided	Focus groups and survey: value for patient care; Chart review: procedures avoided	None	**Quantitative** Survey, chart review
Yeager, *et al.,* 2014[137]	Barriers to implementation of LaHIE as identified by interviews with health care representatives	NA	NA	**Qualitative, content analysis**

Author, Year	Results	Risk of Bias
Winden, *et al.,* 2014[71]	Focus groups: provided value for patient care, especially for avoiding duplicate testing and detecting drug-seeking behavior; Survey: 74% agreed provided value in patient care; Chart review: 560 procedures avoided in 237 notes out of 1,488 assessed	Moderate
Yeager, *et al.,* 2014[137]	"Findings suggest that Meaningful Use requirements are a critical factor influencing the decision to participate in the HIE, specifically the mandate that hospitals be able to electronically transfer summary of care documents. Creating buy-in within a few large hospital networks legitimized the HIE and hastened interest in those markets. Fees charged by electronic health record (EHR) vendors to develop HIE interfaces have been prohibitive. Funding from the federal incentive program is intended to offset the costs associated with EHR implementation and increase the likelihood that HIEs can provide value to the population; however, costs and time delays of EHR interface development may be key barriers to fully integrated HIEs. State HIEs may benefit from targeted involvement of state health care leaders who can champion the potential value of the HIE"	Moderate

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
eHealth Initiative 2013 Report[73]	Cross-sectional	To assess the status of data exchange in the U.S.	Nationwide	Any	**Survey responses**	2013; comparison to 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
eHealth Initiative 2013 Report[73]	Various	199 of 315 completed the survey; these were a mix of community data exchanges, statewide efforts, & healthcare delivery organizations.	Varies	315 data exchange initiatives were identified

Author, Year	N Sample Description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
eHealth Initiative 2013 Report[73]	-199 of 315 completed the survey; these were a mix of community data exchanges, statewide efforts, & healthcare (HC) delivery organizations. -90 organizations self-identified as community-based HIEs; 45 as state; 50 as health care delivery organizations. -There is no single dominant model for HIE; 125 organizations used a query model, 124 used secure electronic messaging; 111 used end-to-end integration; 84 used a combination of models. -'Direct' is a standards-based protocol for securely exchanging data; 90 organizations use M117'Direct', mostly in transitions of care. -Patient consent for data exchange generally remains an 'all-or-nothing' proposition, with 'opt-out' the most common consent model.	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
eHealth Initiative 2013 Report[73]	-Number of initiatives reaching 'advanced stages of operation, sustainability or innovation (as defined by eHI's developmental framework) -Number of years to become operational -Trends in use since 2011 -Number of organizations self-identifying as community, state-, or HC delivery system -Types of professionals most commonly providing and using data -Types of data most commonly provided/viewed -Number having hired personnel from ONC's Workforce Development Program (WDP) -Protocol used for securely exchanging information -Key Findings -Issues for the future	NR	NR	**NR**

Author, Year	Results	Risk of Bias
eHealth Initiative 2013 Report[73]	84 organizations had reached an 'advanced' stage of operation, sustainability, or innovation. Most took 2 years to become operational. Among organizations responding in 2011 and 2013, 27 more had reached stages 5, 6, or 7 in 2013. 90 organizations self-identified as community-based HIEs; 45 as state-; 50 as HC delivery organizations. Hospitals and Am Care providers are stakeholders most commonly providing/viewing data. Labs also commonly provide data. Community public health clinics commonly view data. 24 reported they had hired staff from the ONC's WDP, compared to only 3 in 2011. 'Direct' is a standards-based protocol for securely exchanging data; 90 organizations use 'Direct', mostly in transitions of care. There is no single dominant model for HIE; 125 organizations used a query model, 124 used secure electronic messaging; 111 used end-to-end integration; 84 used a combination of models. **Key Findings:** 1) Achieving interoperability with disparate information systems is a major concern; 68 initiatives have had to connect with more than 10 different systems; 2) To overcome interoperability challenges, exchanges would like to see standardized pricing and integration solutions from vendors; 3) Many exchanges are not sharing data with competing organizations; 4) Exchanges are focusing on functionalities to support health reform and advance analytics; 5) Patient engagement remains low amongst organizations exchanging data; 6) Patient consent for data exchange generally remains an 'all-or nothing' proposition, with 'opt-out' the most common consent model; 7) Since 2011, more initiatives have become more financially viable. However, hospitals and payers are still expected to fund most exchange activity; of the 51 that were NOT sustainable, 31 (of 51) receive more than 50% of their funding from the federal government and 22 report they are a state-HIE. Overall, in 2011, 16 reported they were sustainable; in 2013, 35 reported they were sustainable. Organizations realize the precariousness of government funding and are trying to offer valuable services for a fee. **Issues for the future:** 1) Interoperability concerns need to be addressed; 2) Health reform provides exchanges an opportunity to show value; 3) Patient engagement remains poor.	NA

Author, Year	Study Design	Study Purpose/Research Question	Geographic Location	Setting	Data Source(s)/ Evaluation Data	Time Period of Data Collection
eHealth Initiative 2014 Report[74]	Cross-sectional	To assess the status of data exchange in the US.	Nationwide	Any	**Survey responses**	2013; comparison to 2011

Author, Year	Name of HIE (Intervention)	Description of HIE (this will become Types)	Date HIE Implemented	Population
eHealth Initiative 2014 Report[74]	Various	199 of 315 completed the survey; these were a mix of community data exchanges, statewide efforts, & healthcare delivery organizations.	Varies	315 data exchange initiatives were identified

Author, Year	N Sample description (if applicable)	Inclusion Criteria	Exclusion Criteria	Comparator or Comparison
eHealth Initiative 2014 Report[74]	-199 of 315 completed the survey; these were a mix of community data exchanges, statewide efforts, & healthcare (HC) delivery organizations. -90 organizations self-identified as community-based HIEs; 45 as state; 50 as health care delivery organizations. -There is no single dominant model for HIE; 125 organizations used a query model, 124 used secure electronic messaging; 111 used end-to-end integration; 84 used a combination of models. -'Direct' is a standards-based protocol for securely exchanging data; 90 organizations use M117'Direct', mostly in transitions of care. -Patient consent for data exchange generally remains an 'all-or-nothing' proposition, with 'opt-out' the most common consent model.	NR	NR	NA

Author, Year	Outcomes Measured	Independent Variables	Confounding Variables	Analysis Methods
eHealth Initiative 2014 Report[74]	-Number of initiatives reaching 'advanced stages of operation, sustainability or innovation (as defined by eHI's developmental framework) -Number of years to become operational -Trends in use since 2011 -Number of organizations self-identifying as community, state-, or HC delivery system -Types of professionals most commonly providing and using data -Types of data most commonly provided/viewed -Number having hired personnel from ONC's Workforce Development Program (WDP) -Protocol used for securely exchanging information -Key Findings -Issues for the future	NR	NR	NR

Author, Year	Results	Risk of Bias
eHealth Initiative 2014 Report[74]	Who provides data: 112 hospitals, 100 Am Care providers, 56 labs, 52 community/public health clinics. Who accesses data: 111 Am Care providers, 104 hospitals, 75 community/public health clinics, 65 behavioral or mental health providers. Key Barriers: 1) Cost and technical challenges are key barriers to interoperability; 2) Regulatory policies appear to have prompted increased use of core HIE services such as 'Direct', care summary exchange, and transitions of care; 3) Advanced initiatives are supporting new payment and advanced delivery models; 4) Sustainable organizations have replaced federal funding with revenue from fees and membership dues. Key finding 1: Interoperability Challenges include costs of building interfaces, getting consistent and timely response from EMR vendors and interface developers, and technical difficulty of building interfaces. 112 organizations have had to construct multiple interfaces and 18 have had to construct more than 25 interfaces. Suggestions for overcoming interoperability challenges include: 1) standardized pricing and integration solutions from vendors; 2) 'plug and play' platform; 3) federally mandated standards; 4) cultural changes in willingness to share data; 5) greater use among providers of consensus-based standards. Key finding 2: Regulatory Policies prompt use of core HIE Services: 101 incorporate secure messaging into their models; 78 offer a 'Direct' address directory; more respondents are using 'Direct' for all given use cases (when compared to last year). 74 have met at least one Stage 2 Meaningful Use criteria. 7 stages of Development are delineated (see slide in report for detail); Key finding 3: Advanced initiatives are supporting new payment & delivery models: 106 reported they have reached stage 6 (operating) or higher on the eHI's HIE maturity scale (an increase of 11% over 2013). 64 support an ACO; 52 support a PCMH; 21 support a State Innovation Model; 12 support a bundled payment initiative. Key finding 4: Sustainable groups replace fed funding with fees and membership dues: 45 use fees to completely cover operational expenses; 38 use fees but need additional funding. 41 report that dues or fees are greatest revenue source; 89 believe dues or fees will eventually be their primary revenue stream. 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 and a standard approach to sustainability (sub-bullet: despite expiration of large funding sources, radical changes in overall landscape are not evident); 3) As organizations mature, they will offer new and innovative services (public health has already leverages HIE; alert notification services may help ACOs to track patients); 4) Organizations are encouraged to work collaboratively to overcome remaining challenges (especially work with regional/community partners to avoid creating 'pockets' of exchange).	NA

* this is from billing data, not EHR

†one site dropped that didn't have comparable qualitative data.

A1c= glycated hemoglobin; AHA= American Hospital Association; AHRQ= Agency for Healthcare Research and Quality; aka= also known as; AMIE= Arizona medical information exchange; ANOVA= analysis of variance; BHIX= Brooklyn Health Information Exchange; CCD= continuity of care document; CCHIT= Certification Commission for Healthcare Information Technology; CCR= community care record; CCS= clinical classification software; CD4= HIV helper cell count; CDA = clinical document architecture; CDC= Centers for Disease Control and Prevention; CE= Care Everywhere; CEN= clinical event notification; CHIC RHIO= Carolina HIV information cooperative regional health information organization; CI= confidence interval; CIO= chief information officer; COACH= Community Oriented Approach to Coordinated Healthcare; CPT4= Current procedure Terminology; CT= computed axial tomography scan; DOD= Department of Defense; e= electronic; e.g.= for example; ebSML RIM= electronic business using extensible markup language registry information model; ebXML RS= electronic business using extensible markup language; ECCI= Electronic Clinical Communication Implementation Program; ED= emergency department; EDI= electronic data interchange; EDIFACT= electronic data interchange for administration, commerce and transport; eHIE= electronic health information exchange; EHR= electronic health records; EKG= electrocardiogram; ELRs = enhanced laboratory reports; EMR= electronic medical records; EMS= emergency medical services; e-OP= electronic outpatient appointment booking; EPIC= electronic privacy information center; et al.= and others; etc.= etcetera; EPR= electronic patient records; e-RR= electronic results reporting; EU27= 27 nations in the European Union; FITT= fit between individuals tasks and technologies; FUHN= Federally Qualified Health Center Urban Health network; FQHCs= federally qualified health centers; GDP= gross domestic product; GP= general practitioner; HC= Health Care; HCAHPS= Hospital Consumer Assessment of Healthcare Providers and Systems; HEAL = Health Care Efficiency and Affordability Law; HEAL NY= Health Care Efficiency and Affordability Law for New York; HEDIS= health care effectiveness data and information set; HIE= health information exchange; HIMSS= healthcare information and management systems society; HIMSS-AD= healthcare information and management systems society analytical database; HIO= Health Insuring Organization; HIPAA= Health Insurance Portability and Accountability Act; HITECH= Health Information Technology for Economic & Clinical Health Act; HL-7= Health Level 7; HL7; HMO= health maintenance organization; HRR= unadjusted hazard ratio; HRSA= `Health Resources and Services Administration; Id = Identifier; i.e.= that is; ICC= integrated care collaboration; ICD-9= Ninth Revision of the International Classification of Diseases; ICD-9-CM= International Classifications of Diseases, Clinical Modification; ICU= intensive care unit; IDS= integrated delivery system; I-EMS= Indianapolis Emergency Medical Services; IHIE= Indiana Health Information Exchange; IM & T=information management & technology; INPC= Indiana Network fro Patient Care; IOM= Institute of Medicine's; IQR= interquartile range; IS = information system; IT= information technology; KP= Kaiser Permanente?;

LaHIE=Louisiana HIE; LaPHIE= Louisiana Public Health Information Exchange; LBNH= Long Beach Network for Health; LOINC= Logical Observation Identifiers Names and Codes; MAeHC= Massachusetts eHealth Collaborative; MANOVA= multivariate analysis of variance; MD= Doctor of Medicine; MEGAHIT= Medical Evidence Gathering Through Health IT; MHDC= Massachusetts Health Data Consortium; mL= milliliter; mm= millimeter; MN= Minnesota; MPI= master patient index; MRI= magnetic resonance imaging; MRSA= Methicillin Resistant Staphylococcus Aureus; MSeHA= MidSouth e-Health Alliance; N= sample size; NA= not applicable; NAMCS= National Ambulatory Medical Care Survey; NDC= National Drug Code; NE= northeast; NHIN= Nationwide Health Information Network; NLM= National Library of Medicine; NR= not relevant; NS= not significant; NY= New York; NYCLIX= New York Clinical Information Exchange; OLS= ordinary least squares; ONC= Office of the National Coordinator for Health Information Technology; OR= odds ratio; PBMs= pharmacy benefit managers; PC= primary care; PCP = primary care provider; PDF= portable document format; PHI= personal health information; PHR= personal health record; PPO= preferred provider organization; QUIS= Questionnaire for User Interaction Satisfaction; RCT= randomized, controlled trial; RHIE = regional health information exchange; RHIO= regional health information organization; RLS= record locator service; RNA= ribonucleic acid; RR= relative risk; SCR= summary care record; SD= standard deviation; S.E.= southeast; SF-12= Short Form-12 item survey; SHIN-NY= Statewide Health Information Network for New York; SMRTnet= Secure Medical Records Transfer Network; SNOCAP-USA= State Networks of Colorado Ambulatory Practices & Partners United States of America; SNOMED= Systemized Nomenclature of Medicine; SSA= Social Security Administration; SUNBH = Seoul National University Bundang Hospital; TILAK= Tiroler Landeskrankenanstaleten ; TOE= technological, organizational and environmental; TUMA= Trans-mural exchange of medication data in Almere; U.K.= United Kingdom; U.S.= United States; URL= uniform resource locator; USB= universal serial bus; VA= U.S. Department of Veterans Affairs; VL= viral load; VLER= Veterans Lifetime Electronic Record; VRE= Vancomycin resistant enterococci; vs.= versus; WHIE= Wisconsin Health Information Exchange; XML= extensible markup language.

Appendix G. Risk of Bias Assessment Criteria

Our assessment of risk of bias was based on the recommendations in the Agency for Healthcare Research and Quality Methods Guide for Effectiveness and Comparative Effectiveness Reviews.[1] Included studies were classified according to type of design (see **Appendix E**) as part of the data abstraction phase, and each major type of study was assessed for bias according to relevant criteria. This criteria included questions that assessed selection bias, performance bias, detection bias, attrition bias, and reporting bias (i.e., those about adequacy of randomization, similarity of groups at baseline, appropriateness of the comparators, consideration of concurrent interventions or unintended exposures, quantity of missing data, methods of handling missing data, identification and assessment of important confounding variables, use of intention-to-treat analysis, reliability and validity of outcome measures, and reporting of pre specified outcomes).

Criteria for Randomized Controlled Trials

<u>Selection bias</u>
- Was randomization adequate?
- Was allocation concealment adequate?
- Were groups similar at baseline?
- Did the study maintain comparable groups throughout the study?
- Was the eligibility criteria specified?

<u>Detection bias</u>
- Was the study adequately blinded (outcome assessor, care provider, and patient)?

<u>Attrition bias</u>
- Was the loss to followup not differential or high?

<u>Reporting bias</u>
- Did the study report attrition, crossovers, adherence, and contamination?
- Was an intention-to-treat analysis used?
- Were outcomes prespecied?

Criteria for Cohort, Case-Control, and Other Observational Studies

<u>Selection bias</u>
- Are the comparison groups or time periods appropriate?
- Were the inclusion and exclusion criteria specified and applied equally to each group?
- Did the design and analyses account for important potential confounding and modifying variables appropriately?
- Were valid and reliable measures used (inclusion/exclusion, confounding, outcomes)?

<u>Detection bias</u>
- Were non-biased and valid ascertainment methods used (inclusion/exclusion, confounding, outcomes)?

- Was the timing and/or time period for the measurement of the intervention and outcomes appropriate?

<u>Attrition bias</u>

- Was there NO missing data? If missing data, was it handled appropriately?

<u>Reporting bias</u>

- Were outcomes prespecified and were prespecified outcomes reported?

Definition of ratings based on above criteria:

Low risk of bias:

Studies rated "low risk of bias" were considered to have the least risk of bias, and their results are considered valid. Low risk of bias studies include clear descriptions of the population, setting, interventions, and comparison groups clear reporting of missing data; appropriate means for preventing bias; and appropriate measurement of outcomes.

Moderate risk of bias:

Studies rated "moderate risk of bias" were susceptible to some bias, though not enough to necessarily invalidate the results. These studies may not meet all the criteria for a rating of low risk of bias, but do not have flaws likely to cause major bias. The study may be missing information, making it difficult to assess limitations and potential problems. The moderate risk of bias category is broad, and studies with this rating will vary in their strengths and weaknesses. The results of some moderate risk of bias studies are likely to be valid, while others may be only possibly valid.

High risk of bias:

Studies rated "high risk of bias" have significant flaws that imply biases of various types that may invalidate the results. They will have a serious or "fatal" flaw in design, analysis, or reporting; large amounts of missing information; or discrepancies in reporting. The results of these studies will be least as likely to reflect flaws in the study design as the true difference between the compared interventions. We did not exclude studies rated as being high risk of bias a priori, but high risk of bias studies were considered to be less reliable than lower risk of bias studies when synthesizing the evidence, particularly if discrepancies between studies were present.

Criteria for Surveys, Focus Groups, and Interview Studies

<u>Selection bias</u>

1. Is the sampling strategy or selection criteria reported and appropriate?
2. Are the response or participation rates reported and are they acceptable given the type of study?
3. Are characteristics (e.g., demographics) of respondents/participants reported?

<u>Detection bias</u>

4. Is how the questions were developed/selected reported and is it appropriate?
5. Were confounders considered (could be in analysis or presentation, such as stratifying results)?

<u>Other</u>

6. Is analysis appropriate (given the type of data)?

Reference for Appendix G

1. Methods Guide for Effectiveness and Comparative Effectiveness Reviews. AHRQ Publication Number 10(14)-EHC062-EF. Rockville, MD: Agency for Healthcare Research and Quality. January 2014. Available at: www.effectivehealthcare.ahrq.gov. Accessed April 18, 2014. PMID: 21433403.

Appendix H. Strength of Evidence Criteria[1]

The set of five required domains comprises the main constructs that Evidence-based Practice Centers (EPCs) should use for all major outcomes and comparisons of interest. As briefly defined below in Table H1, these domains represent related but separate concepts and each is scored independently. The concepts are explained in more detail below.

Table H1. Required domains and their definitions

Domain	Definition and Elements	Score and Application
Study Limitations	Study limitations is the degree to which the included studies for a given outcome have a high likelihood of adequate protection against bias (i.e., good internal validity), assessed through two main elements: • Study design: Whether RCTs or other designs such as nonexperimental or observational studies. • Study conduct. Aggregation of ratings of risk of bias of the individual studies under consideration.	Score as one of three levels, separately by type of study design: • Low level of study limitations • Medium level of study limitations • High level of study limitations
Directness	Directness relates to (a) whether evidence links interventions directly to a health outcome of specific importance for the review, and (b) for comparative studies, whether the comparisons are based on head-to-head studies. The EPC should specify the comparison and outcome for which the SOE grade applies. Evidence may be indirect in several situations such as: • The outcome being graded is considered intermediate (such as laboratory tests) in a review that is focused on clinical health outcomes (such as morbidity, mortality). • Data do not come from head-to-head comparisons but rather from two or more bodies of evidence to compare interventions A and B—e.g., studies of A vs. placebo and B vs. placebo, or studies of A vs. C and B vs. C but not direct comparisons of A vs. B. • Data are available only for proxy respondents (e.g., obtained from family members or nurses) instead of directly from patients for situations in which patients are capable of self-reporting and self-report is more reliable. Indirectness always implies that more than one body of evidence is required to link interventions to the most important health outcome.	Score as one of two levels: • Direct • Indirect If the domain score is indirect, EPCs should specify what type of indirectness accounts for the rating.
Consistency	Consistency is the degree to which included studies find either the same direction or similar magnitude of effect. EPCs can assess this through two main elements: • Direction of effect: Effect sizes have the same sign (that is, are on the same side of no effect or a MID) • Magnitude of effect: The range of effect sizes is similar. EPCs may consider the overlap of CIs when making this evaluation. The importance of direction vs. magnitude of effect will depend on the key question and EPC judgments.	Score as one of three levels: • Consistent • Inconsistent • Unknown (e.g., single study) Single-study evidence bases (including mega-trials) cannot be judged with respect to consistency. In that instance, use “Consistency unknown (single study).”

Domain	Definition and Elements	Score and Application
Precision	Precision is the degree of certainty surrounding an effect estimate with respect to a given outcome, based on the sufficiency of sample size and number of events. • A body of evidence will generally be imprecise if the OIS is not met. OIS refers to the minimum number of patients (and events when assessing dichotomous outcomes) needed for an evidence base to be considered adequately powered. • If EPCs performed a meta-analysis, then EPCs may also consider whether the CI crossed a threshold for an MID. • If a meta-analysis is infeasible or inappropriate, EPCs may consider the narrowness of the range of CIs or the significance level of p-values in the individual studies in the evidence base.	Score as one of two levels: • Precise • Imprecise A precise estimate is one that would allow users to reach a clinically useful conclusion (e.g., treatment A is more effective than treatment B).
Reporting Bias	Reporting bias results from selectively publishing or reporting research findings based on the favorability of direction or magnitude of effect. It includes: • Study publication bias, i.e., nonreporting of the full study. • Selective outcome reporting bias, i.e., nonreporting (or incomplete reporting) of planned outcomes or reporting of unplanned outcomes. • Selective analysis reporting bias, i.e., reporting of one or more favorable analyses for a given outcome while not reporting other, less favorable analyses. Assessment of reporting bias for individual studies depends on many factors–e.g. availability of study protocols, unpublished study documents, and patient-level data. Detecting such bias is likely with access to all relevant documentation and data pertaining to a journal publication, but such access is rarely available. Because methods to detect reporting bias in observational studies are less certain, this guidance does not require EPCs to assess it for such studies.	Score as one of two levels: • Suspected • Undetected Reporting bias is suspected when: • Testing for funnel plot asymmetry demonstrates a substantial likelihood of bias, And/or • A qualitative assessment suggests the likelihood of missing studies, analyses, or outcomes data that may alter the conclusions from the reported evidence. Undetected reporting bias includes all alternative scenarios.

CI = confidence internal; EPC = Evidence-based Practice Center; MID = minimally important difference; OIS = optimal information size; RCT = randomized controlled trial[SOE = strength of evidence

Study Limitations Domain Definition

Scoring the study limitations domain is the essential starting place for grading strength of the body of evidence. It refers to the judgment that the findings from included studies of a treatment (or treatment comparison) for a given outcome are adequately protected against bias (i.e., have good internal validity), based on the design and conduct of those studies. That is, EPCs assess the ability of the evidence to yield an accurate estimate of the true effect without bias (nonrandom error).

Directness Domain Definition

Directness of evidence expresses how closely available evidence measures an outcome of interest. Assessing directness has two parts: directness of outcomes and directness of comparisons. Applicability of evidence (external validity) is considered explicitly but separately from strength of evidence.

Consistency Domain Definition

Consistency refers to the degree of similarity in the direction of effects or the degree of similarity in the effect sizes (magnitudes of effect) across individual studies within an evidence base. EPCs may choose which of these two notions of consistency (direction or magnitude) they are scoring; they should be explicit about this choice.

Precision Domain Definition

Precision is the degree of certainty surrounding an estimate of effect with respect to an outcome. It is based on the potential for random error evaluated through the sufficiency of sample size and, in the case of dichotomous outcomes, the number of events. A precise body of evidence should enable decisionmakers to draw conclusions about whether one treatment is inferior, equivalent, or superior to another.

Reporting Bias Definition

Reporting bias occurs when authors, journals, or both decide to publish or report research findings based on their direction or magnitude of effect. Table 2 defines the three main types of reporting bias that either authors or journals can introduce: publication bias and outcome and analysis reporting bias.

Four Strength of Evidence Levels

The four levels of grades are intended to communicate to decisionmakers EPCs' confidence in a body of evidence for a single outcome of a single treatment comparison. Although assigning a grade requires judgment, having a common understanding of the interpretation will be useful for helping EPCs as they conduct their own global assessment and for improving consistency across reviewers and EPCs.

Table H2 summarizes the four levels of grades that EPCs use for the overall assessment of the body of evidence. Grades are denoted high, moderate, low, and insufficient. They are not designated by Roman numerals or other symbols. EPCs should apply discrete grades and should not use designations such as "low to moderate" strength of evidence.

Table H2. Strength of evidence grades and definitions

Grade	Definition
High	**We are very confident that the estimate of effect lies close to the true effect for this outcome.** The body of evidence has few or no deficiencies. We believe that the findings are stable, i.e., another study would not change the conclusions.
Moderate	**We are moderately confident that the estimate of effect lies close to the true effect for this outcome.** The body of evidence has some deficiencies. We believe that the findings are likely to be stable, but some doubt remains.
Low	**We have limited 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). We believe that additional evidence is needed before concluding either that the findings are stable or that the estimate of effect is close to the true effect.
Insufficient	**We have no evidence, we are unable to estimate an effect, or we have 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.

Each level has two components. The first, principal definition concerns the level of confidence that EPCs place in the estimate of effect (direction or magnitude of effect) for the benefit or harm; this equates to their judgment as to how much the evidence reflects a true effect. The second, subsidiary definition involves an assessment of the level of deficiencies in the body of evidence and belief in the stability of the findings, based on domain scores and a more holistic, summary appreciation of the possibly complex interaction among the individual domains.

Assigning a grade of high, moderate, or low implies that an evidence base is available from which to estimate an effect for either the benefit or the harm. The designations of high, moderate, and low should convey how confident EPCs would be about decisions based on evidence of differing grades, which can be based on either quantitative or qualitative assessment.

For comparative effectiveness questions, the comparison is typically a choice of either direction (A>B, A=B, A<B) or magnitude (difference between A and B). In some instances assigning different grades regarding the direction and the magnitude of an effect may be appropriate. An example of this situation is when studies consistently find that an intervention improves an outcome (e.g., apnea-hypopnea index is reduced by a statistically significant amount or beyond a minimally important difference), but the degree of heterogeneity about the estimate is high (e.g., range -10 to -46 events/minute; $I^2 = 86\%$).

The importance of the distinctions among high, moderate, and low levels (and the distinction with insufficient strength of evidence) can vary by the type of outcome, comparison, and decisionmaker. EPCs understand that some stakeholders may want to take action only when evidence is of high or moderate strength, whereas others may want to understand clearly the implications of low versus insufficient evidence. Even when strength of evidence is low or insufficient, consumers, clinicians, and policymakers may find themselves in the position of having to make choices and decisions, and they may consider factors other than the evidence from a specific systematic review, such as patient values and preferences, costs, or resources.

Reference for Appendix H

1. Methods Guide for Effectiveness and Comparative Effectiveness Reviews. AHRQ Publication No. 10(13)-EHC063-EF. Rockville (MD) :Agency for Healthcare Research and Quality. January 2014. Availible at: www.effectivehealthcare.ahrq.gov.

Appendix I. Quality Assessment Tables

Table I-1. Quality assessments of randomized controlled trials

Author, Year	Randomization adequate?	Allocation concealment adequate?	Groups similar at baseline?	Maintain Comparable Groups?	Eligibility criteria specified?	Outcome assessors masked?	Care provider masked?	Patient masked?
Afilalo, et al., 2007[66] Lang, et al., 2006[65]	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Willis, et al., 2013[67]	Yes	Not Reported	Unclear	Unclear	Yes	Unclear	No	No

Author, Year	Reporting of attrition, crossovers, adherence, and contamination	No Loss to followup: differential/ high	Intention-to-treat analysis	No Post-randomization exclusions	Outcomes Prespecified	Funding source	Risk of bias
Afilalo, et al., 2007[66] Lang, et al., 2006[65]	Unclear	No	No	No	Yes	Yes	Moderate
Willis, et al., 2013[67]	Yes	Yes	Yes	Yes	Yes	Agency for Healthcare Research and Quality	Moderate

Table I-2. Quality assessments of cohort, case-control, and other observational studies

Author, Year	Are the comparison groups or time periods appropriate?	Were the inclusion and exclusion criteria specified and applied equally to each group?	Did the design and analyses account for important potential confounding and modifying variables appropriately?	Were valid and reliable measures used? (inclusion/exclusion, confounding, outcomes)	Were non-biased and valid ascertainment methods used? (inclusion/exclusion, confounding, outcomes)	Was the timing and/or time period for the measurement of the intervention and outcomes appropriate?
Bailey, et al., 2013[40]	Yes	Yes	Yes	Yes	NR	Yes
Bailey, et al., 2012[39]	Yes	Yes	Yes	Yes	NR	Yes
Ben-Assuli, Shabtai, and Leshno, 2013[41]	Yes	NR	Yes	Yes	NR	Yes
Ben-Assuli, Shabtai, and Leshno, 2015[72]	Yes	Yes	Yes	Yes	NR	Yes
Carr, et al., 2014[70]	No	No	Unclear	NR	Yes	Yes
Dixon, McGowan, and Grannis, 2011[42]	Yes	NA	NA	Yes	Yes	NA
Feldman and Horan 2011[43]	Yes	No	No	Yes	Yes	Yes
Frisse, et al., 2012[44]	Yes	Yes	Yes	Yes	NR	Yes
Jones, Friedberg and Schneider, 2011[68]	Yes	Yes	Yes	Yes	Yes	Yes
Kern et al., 2012[45]	Yes	Yes	Yes	Yes	Yes	Yes
Kho et al., 2013[88]	NA	Yes	No	Yes	Yes	Yes
Lammers, Adler-Milstein, and Kocher, 2014[69]	Yes	Yes	Yes	Yes	Yes	Yes
Lobach, et al., 2007[100]	NA	NA	NA	Yes	NA	Yes
Magnus, et al., 2012[47]	Yes	Yes	Yes	Yes	Yes	Yes

Author, Year	Was there no missing data? If missing data, was it handled appropriately?	Were outcomes prespecified and were prespecified outcomes reported?	Risk of bias
Bailey, et al., 2013[40]	Yes	Yes	Low
Bailey, et al., 2012[39]	NR	Yes	Low
Ben-Assuli, Shabtai, and Leshno, 2013[41]	Yes	Yes	Low
Ben-Assuli, Shabtai, and Leshno, 2015[72]	Yes	Yes	Low
Carr, et al., 2014[70]	Yes	Yes	Moderate
Dixon, McGowan, and Grannis, 2011[42]	NA	Yes	Low
Feldman and Horan 2011[43]	No	Yes	Moderate
Frisse, et al., 2012[44]	Yes	Yes	Moderate
Jones, Friedberg and Schneider, 2011[68]	Yes	Yes	Low
Kern et al., 2012[45]	No	Yes	Low
Kho et al., 2013[88]	Yes	NA	Low
Lammers, Adler-Milstein, and Kocher, 2014[69]	Yes	Yes	Low
Lobach, et al., 2007[100]	Unclear	NA	Low
Magnus, et al., 2012[47]	NR	Yes	Low

Author, Year	Are the comparison groups or time periods appropriate?	Were the inclusion and exclusion criteria specified and applied equally to each group?	Did the design and analyses account for important potential confounding and modifying variables appropriately?	Were valid and reliable measures used? (inclusion/exclusion, confounding, outcomes)	Were non-biased and valid ascertainment methods used? (inclusion/exclusion, confounding, outcomes)	Was the timing and/or time period for the measurement of the intervention and outcomes appropriate?
Mäenpää, et al., 2011[115]	Yes	Yes	Yes	Yes	Yes	Yes
McCarthy, et al., 2014[161]	Unclear	Yes	No	No	No	Yes
McGowan, et al., 2007[148]	No	No	No	No	No	No
Miller and Tucker, 2014[149]	Yes	Yes	No	Yes	No	Yes
Moore, et al., 2012[106]	No comparison group	Yes	No	Yes	No	Yes
Nagykaldi, et al., 2014[48]	Yes	Unclear	Unclear	Unclear	Unclear	Yes
Onyile, et al., 2013[125]	Yes	Yes	NA	Yes	Yes	Yes
Overhage, Grannis, and McDonald, 2008[49]	Yes	Yes	Yes	Yes	Yes	Yes
Ross, et al., 2013[50]	Yes	Yes	Yes	Yes	Yes	Yes
Saff, et al., 2010[154]	NA	NA	No	Uncertain	Unclear	Yes
Shapiro, et al., 2013[51]	Yes	Yes	Yes	Yes	Yes	Yes
Silvester and Carr, 2009[114]	Yes	Yes	No	Yes	Yes	Yes

Author, Year	Was there no missing data? If missing data, was it handled appropriately?	Were outcomes prespecified and were prespecified outcomes reported?	Risk of bias
Mäenpää, et al., 2011[115]	Yes	Yes	Low
McCarthy, et al., 2014[161]	NA	No	Moderate
McGowan, et al., 2007[148]	Unclear	No	High
Miller and Tucker, 2014[149]	Potentially missing data handled to best of their ability	Yes	Moderate
Moore, et al., 2012[106]	Yes	Yes	Moderate
Nagykaldi, et al., 2014[48]	NR	Yes	Moderate
Onyile, et al., 2013[125]	Not clear	NA	Low
Overhage, Grannis, and McDonald, 2008[49]	Yes	Yes	Low
Ross, et al., 2013[50]	Unclear	Yes	Low
Saff, et al., 2010[154]	Unclear	No	High
Shapiro, et al., 2013[51]	Yes	Yes	Moderate
Silvester and Carr, 2009[114]	Yes	Yes	High

Author, Year	Are the comparison groups or time periods appropriate?	Were the inclusion and exclusion criteria specified and applied equally to each group?	Did the design and analyses account for important potential confounding and modifying variables appropriately?	Were valid and reliable measures used? (inclusion/exclusion, confounding, outcomes)	Were non-biased and valid ascertainment methods used? (inclusion/exclusion, confounding, outcomes)	Was the timing and/or time period for the measurement of the intervention and outcomes appropriate?
Tzeel, Lawnicki, and Pemble, 2012[53]	Yes	Yes	Yes	Yes	Unclear	Yes
Tzeel, Lawnicki, and Pemble, 2011[52]	Yes	Yes	Yes	Yes	Unclear	Yes
Vest, 2009[54]	Yes	Yes	Yes	Yes	Yes	Yes
Vest, 2010[155]	Yes	Yes	Yes	Yes	Yes	Yes
Vest, et al., 2011[104]	Yes	Yes	Yes	Yes	Yes	Yes
Vest, et al., 2011[105]	Yes	Yes	Yes	Yes	Yes	Yes
Vest and Miller, 2011[64]	Yes	Yes	Yes	Yes (no information on survey reporting)	Yes (Data are from multiple surveys)	Yes
Vest, et al., 2012[101]	Yes	Yes	Yes	Yes	Yes	Yes
Vest and Jasperson, 2012[103]	No comparison group; time period appropriate	Yes	Yes	Yes	Yes	Yes
Vest, et al., 2013[102]	Unclear	Yes	No	Yes	No	No
Vest, et al., 2014[55]	Yes	Yes	Yes	Yes	Yes	Yes
Vest, et al., 2014[56]	Yes	Yes	No	Yes	Yes	Yes
Winden, 2014[71]	No	Yes	No	Unclear	Unclear	Yes

Author, Year	Was there no missing data? If missing data, was it handled appropriately?	Were outcomes prespecified and were prespecified outcomes reported?	Risk of bias
Tzeel, Lawnicki, and Pemble, 2012[53]	Yes	Yes	Low
Tzeel, Lawnicki, and Pemble, 2011[52]	Yes	Yes	Low
Vest, 2009[54]	Yes	Yes	Low
Vest, 2010[155]	Yes	Yes	Low
Vest, et al., 2011[104]	Not clear	Yes	Low
Vest, et al., 2011[105]	Not clear	Yes	Low
Vest and Miller, 2011[64]	Unclear	Yes	Low
Vest, et al., 2012[101]	Unclear	Yes	Low
Vest and Jasperson, 2012[103]	Yes	Yes	Low
Vest, et al., 2013[102]	Not clear	Yes	Low
Vest, et al., 2014[55]	Not clear	Yes	Low
Vest, et al., 2014[56]	Not clear	Yes	Low
Winden, 2014[71]	No	Yes	Moderate

NA= not applicable; NR = not relevant.

Table I-3. Quality assessment of surveys, focus groups, and interview studies

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Abramson, et al., 2012[76]	Yes	Yes, 72%	Yes, hospitals in New York State	Yes
Abramson, et al., 2014[77]	Yes	59.3% (375/632) response rate	Yes, nursing homes in New York State	Yes
Abramson, et al., 2014[96]	Yes	Yes	Yes	Yes
Adler-Milstein, et al., 2008[81]	Yes	Yes, 60%		Yes
Adler-Milstein, Bates, and Jha, 2009[78]	Yes	Yes, 78%	Yes, operational RHIOs	Yes, pilot testing
Adler-Milstein, Landefeld, and Jha, 2010[80]	Yes	Yes, 83%	Yes, operational RHIOs	Yes
Adler-Milstein, Bates, and Jha, 2011[79]	Yes	Yes, 84%	Yes, operational RHIOs	Yes
Adler-Milstein, DesRoches, and Jha, 2011[107]	Yes	Yes - 69%	Yes	Yes
Adler-Milstein, Bates, and Jha, 2013[25]	Yes	Yes, 78%	Yes, operational RHIOs	Yes, pilot testing
Adler-Milstein and Jha, 2014[108]	Yes	Yes	Yes	Yes
Altman, et al., 2012[57]	Unclear; convenience sample	Yes, 70% (14/20)	Yes	Yes
Audet, Squires, and Doty, 2014[109]	Yes	Yes, 35%	Yes	Yes
Caffrey and Park- Lee 2013[93]	Yes	Yes	Yes	Yes

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Abramson, et al., 2012[76]	Unclear	Yes	Low
Abramson, et al., 2014[77]	Unclear	Yes	Low
Abramson, et al., 2014[96]	Yes	Yes	Moderate
Adler-Milstein, et al., 2008[81]	Unclear	Yes	Low
Adler-Milstein, Bates, and Jha, 2009[78]	Unclear	Yes	Low
Adler-Milstein, Landefeld, and Jha, 2010[80]	Unclear	Yes	Low
Adler-Milstein, Bates, and Jha, 2011[79]	Unclear	Yes	Low
Adler-Milstein, DesRoches, and Jha, 2011[107]	Yes	Yes	Low
Adler-Milstein, Bates, and Jha, 2013[25]	Unclear	Yes	Low
Adler-Milstein and Jha, 2014[108]	Unclear	Yes	Low
Altman, et al., 2012[57]	NA, descriptive interviews	Mostly descriptive results presented	Moderate
Audet, Squires, and Doty, 2014[109]	Unclear	Yes	Low
Caffrey and Park- Lee 2013[93]	Yes	Yes	Low

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Campion, et al., 2012[58]	Yes	Yes (19%)	Yes	Yes
Codagnone, Lupiañez-Villanueva 2013[94]	Yes	Yes	Yes	Yes
Chang, et al., 2010[59]	No	No, 9 primary care physicians selected for	Yes	yes
Dixon, Miller, and Overhage, 2013[141]	Yes	Yes	Yes	Yes
Dixon, Jones, and Grannis, 2013[83]	Yes	Yes, 69% (44/63)	"Infection preventionists"	Yes, pilot administration with modification of survey
Fairbrother, et al., 2014[143]	Yes	NR but these were interviews	Yes	NR
Finnell and Overhage, 2010[131]	Yes	Yes, 32% response rate	Yes	Unclear. Survey not well described.
Foldy, 2007[84]	Unclear-basically asked experts whom to ask	Yes	No	NR - survey URL broken
Fontaine, et al., 2010[85]	Yes	NR	NR	Yes
Furukawa, 2014[110]	Yes	Yes	Yes	Unclear
Furukawa, 2013[111]	Yes	Yes	No	Yes
Gadd, et al., 2011[86]	Yes	Yes, email survey responses from with 70% response rate from health care professionals (165/237).	Yes	Yes
Genes, et al., 2011[145]	Yes	Yes, 18/22 participated in interviews	Yes	Yes
Goldwater, et al., 2014[146]	Yes	Yes for interviews. 20% response to emailed survey.	No	NR

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Campion, et al., 2012[58]	Yes	Yes	Moderate
Codagnone, Lupiañez- Villanueva 2013[94]	Yes	Yes	Low
Chang, et al., 2010[59]	No, descriptive only	Yes	Moderate
Dixon, Miller, and Overhage, 2013[141]	No	Yes	Moderate
Dixon, Jones, and Grannis, 2013[83]	Unclear	Yes	Moderate
Fairbrother, et al., 2014[143]	NA	NR	High
Finnell and Overhage, 2010[131]	NA	Yes, descriptive only	Moderate
Foldy, 2007[84]	No	Yes	Moderate
Fontaine, et al., 2010[85]	No	Yes	Moderate
Furukawa, 2014[110]	Yes	Yes	Low
Furukawa, 2013[111]	Yes	Yes	Low
Gadd, et al., 2011[86]	Yes	Yes	Low
Genes, et al., 2011[145]	NA	Yes	Low
Goldwater, et al., 2014[146]	NA	Yes, descriptive only	Moderate

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Greenhalgh, et al., 2010[121]	Yes	No	No	Yes
Hamann and Bezboruah, 2013[113]	Yes	Yes	NA	Yes
Hessler, et al., 2009[87]	Yes	No	Yes	Yes
Hincapie, et al., 2011[132]	Yes	Yes	No, no table of participants. Types of providers were mentioned with qualitative themes.	Yes
Hyppönen, et al., 2014[133]	Yes	Yes	Yes	Yes
Jha, et al., 2008[117]	Yes	No	No	No
Kaushal, et al., 2010[60]	No	Yes	No	Yes
Kern, et al., 2009[173]	Yes	Yes	Yes	Yes
Kern, et al., 2011[171]	No	Yes	No	Yes
Kierkegaard, Kaushal, and Vest, 2014[127]	Yes	NA	Yes, characteristics of sites reported and types of HIE users are described but not quantified.	NR
Lee, et al., 2012[89]	Unclear (post given to all, for pre this is unclear)	No (rate given but low; only collected for 2 weeks)	Yes	Yes
Machan, Ammenwerth, and Schabetsberger, 2006[62]	Yes, questionnaire sent to all practitioners registered in HIE project.	Yes, 43% (104/242) practitioners responded.	Yes, physician users of HIE.	Yes, development process for interviews guide and questionnaire described thoroughly. No psychometrics presented.

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Greenhalgh, et al., 2010[121]	Yes	Yes	Low
Hamann and Bezboruah, 2013[113]	Yes	Yes	Low
Hessler, et al., 2009[87]	No	No	High
Hincapie, et al., 2011[132]	NA	Yes	Moderate
Hyppönen, et al., 2014[133]	Yes	Yes	Low
Jha, et al., 2008[117]	No	Unclear	High
Kaushal, et al., 2010[60]	No	Yes	High
Kern, et al., 2009[173]	No	Yes	Moderate
Kern, et al., 2011[171]	No	No	High
Kierkegaard, Kaushal, and Vest, 2014[127]	NA	Yes, coded interviews with Nvivo	Moderate
Lee, et al., 2012[89]	Yes	No	High
Machan, Ammenwerth, and Schabetsberger, 2006[62]	No, only descriptive analysis	Yes, descriptive analysis only.	Low

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Massy-Westropp, et al., 2005[134]	Yes, convenience sample of 82 users of HIE and then additional sample of 50 providers not in HIE program as controls.	Reported as 42% (55/80) but this doesn't account for 50 controls so the response rate is 24% (55/132).	No	No
Maass, et al., 2008[61]	Yes, only 1 person interviewed	NR	NR	NR
McCullough, et al., 2014[135]	Yes, used purposive sample strategy	Yes, reported recruitment rate of practices.	Yes	Yes
Merrill, et al., 2013[174]	Yes	Yes	Yes	Yes
Messer, et al., 2012[138]	Yes, interviews and assessment with 39 stakeholders; pre and post survey of 29 providers' satisfaction with HIE, relationships with other providers, barriers.	NR, it is not clear how many surveys were sent out to compute a response rate.	No	Yes
Miller, 2012[162]	Yes	NR, but these were interviews	NR	Yes, questions developed jointly by the University of California, San Francisco, and Consumers Union
Myers, et al., 2012[128]	Yes, used purposive sample strategy	Yes, 62/102 emailed invitations to survey	Yes for key respondents. No for survey.	Yes, developed after literature review. Reported Chronbach alphas of .57-.97 for scaled items.

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Massy-Westropp, et al., 2005[134]	No	NA	High
Maass, et al., 2008[61]	No	Yes	High
McCullough, et al., 2014[135]	NA	Yes	Low
Merrill, et al., 2013[174]	Yes	Yes	Low
Messer, et al., 2012[138]	NA	Yes, for qualitative and quantitative.	Moderate
Miller, 2012[162]	NA	Yes	Moderate
Myers, et al., 2012[128]	Stratified by role	Yes	Low

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Nøhr, et al., 2001[139]	Yes	Yes	Yes	NR/Yes
Nykänen and Karimaa, 2006[150]	Yes	Yes	No	Yes
Ozkaynak and Brennan, 2013[129]	Yes	NA	Yes	NR
Pagliari, Gilmour, and Sullivan, 2004[122]	Yes	Yes	No	No
Patel, et al., 2013[63]	Yes	Yes	Yes	Yes
Park, et al., 2013[63]	Yes	Yes	Yes	Yes
Phillips, et al., 2014[164]	Yes	NA	No	Yes
Pirnejad, Bal, and Berg, 2008[152]	Yes for RN surveys; No for interviews	Yes	Yes	Yes for surveys - published surveys used to identify questions; No for interviews
Ross, et al., 2010[167]	Yes	Yes	No	Yes
Rudin, et al., 2009[153]	Yes	Not reported	No	Yes
Rudin, et al., 2011[136]	Yes	NR	Yes	Yes/Yes
Schoen, et al., 2012[95]	Yes	Yes	No	No
Sicotte and Paré, 2010[168]	Yes	Yes	NR	Yes
Steward, et al., 2012[169]	Yes	NR but these were interviews	NR	Partnered with UCSF qualitative experts to

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Nøhr, et al., 2001[139]	NA	Yes	Moderate
Nykänen and Karimaa, 2006[150]	No	Yes	Moderate
Ozkaynak and Brennan, 2013[129]	NA	Yes	Moderate
Pagliari, Gilmour, and Sullivan, 2004[122]	No	Yes	Moderate
Patel, et al., 2013[63]	Yes	Yes	Low
Park, et al., 2013[63]	No	Yes	Low
Phillips, et al., 2014[164]	Yes	Yes	Low
Pirnejad, Bal, and Berg, 2008[152]	No	Yes	Moderate
Ross, et al., 2010[167]	No	Yes	Moderate
Rudin, et al., 2009[153]	No	Yes	Moderate
Rudin, et al., 2011[136]	NA	Yes	Low
Schoen, et al., 2012[95]	No	Yes	High
Sicotte and Paré, 2010[168]	Yes	Yes	Low
Steward, et al., 2012[169]	NA	Yes	Moderate

Author, Year	1. Is the sampling strategy or selection criteria reported and appropriate?	2. Are the response or participation rates reported and are they acceptable given the type of study?	3. Are characteristics (e.g., demographics) of respondents/participants reported?	4. Is how the questions were developed/selected reported and is it appropriate?
Soderberg and Laventure, 2013[90]	Yes	Yes	No	Unclear
Thorn, Carter, and Bailey, 2014[130]	Yes, used purposive sample strategy	Yes, mentioned all physicians agreed to participate and no one dropped out.	Yes	Types of questions mentioned but no mention of interview guide.
Unertl, et al., 2013[170]	Yes	Yes	NR	Yes
Unertl, Johnson, and Lorenzi, 2012[119]	Yes	NA	Yes. Characteristics of sites and interviewees described.	NR in main text but mentioned online appendix but no link to access it.
Yeager, et al., 2014[137]	Yes	Yes	Yes	No/Yes. Types of questions mentioned but no mention of interview guide.

Author, Year	5. Were confounders considered? (could be in analysis or presentation, such as stratifying results)	6. Is analysis appropriate? (given the type of data)	Risk of bias
Soderberg and Laventure, 2013[90]	Yes	Yes	Moderate
Thorn, Carter, and Bailey, 2014[130]	NA	Yes	Low
Unertl, et al., 2013[170]	Yes	Yes	Low
Unertl, Johnson, and Lorenzi, 2012[119]	NA	Yes. Coded interviews with Nvivo	Moderate
Yeager, et al., 2014[137]	NA	Yes	Moderate

HIE= health information exchange; NA= not applicable; NR= not relevant; RHIO= regional health information organization; RN= registered nurse; UCSF= University of California, San Francisco; URL= uniform resource locator.