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Health Information Exchange Use (1990-2015): A Systematic Review

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ABSTRACT

Background: In June 2014, the Office of the National Coordinator for Health Information Technology published a 10-year roadmap for the United States to achieve interoperability of electronic health records (EHR) by 2024. A key component of this strategy is the promotion of nationwide health information exchange (HIE). The 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act provided significant investments to achieve HIE.

Objective: We conducted a systematic literature review to describe the use of HIE through 2015.

Methods: We searched MEDLINE, PsycINFO, CINAHL, and Cochrane databases (1990 - 2015); reference lists; and tables of contents of journals not indexed in the databases searched. We extracted data describing study design, setting, geographic location, characteristics of HIE implementation, analysis, follow-up, and results. Study quality was dual-rated using pre-specified criteria and discrepancies resolved through consensus.

Results: We identified 58 studies describing either level of use or primary uses of HIE. These were a mix of surveys, retrospective database analyses, descriptions of audit logs, and focus groups. Settings ranged from community-wide to multinational. Results suggest that HIE use has risen substantially over time, with 82% of non-federal hospitals exchanging information (2015), 38% of physician practices (2013), and 17-23% of long-term care facilities (2013). Statewide efforts, originally funded by HITECH, varied widely, with a small number of states providing the bulk of the data. Characteristics of greater use include the presence of an EHR, larger practice size, and larger market share of the health-system.

Conclusions: Use of HIE in the United States is growing but is still limited. Opportunities remain for expansion. Characteristics of successful implementations may provide a path forward.

Introduction

In the past decade great progress has been made in advancing the health information technology (HIT) infrastructure of the United States.¹ Through the Medicare and Medicaid electronic health record (EHR) incentive programs,² implementation and use of EHRs have become widespread.³⁻⁵ Yet, the sharing of clinical data across disparate health care organizations continues to be hampered by the lack of standardization in EHR features and functionality, and the lack of interoperability among them. To address the latter, in June 2014, the Office of the National Coordinator (ONC) for HIT laid out a 10-year vision and roadmap for the United States to achieve interoperability by 2024.⁶

A key component of the ONC Roadmap, and fundamental to achieving this interoperability, is the promotion of nationwide health information exchange (HIE). HIE is defined as the sharing of electronic clinical data across organizations.⁷ Ideally, HIE allows all types of health care professionals to appropriately access and securely share patients' medical information electronically, across health-systems, with the goal of improved speed, accuracy, and safety; and lower costs.⁷ National governments are making significant investments to achieve HIE. In the US, the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 provided \$564 million for establishment of HIE by states or state-designated entities.⁸

Four previously published systematic reviews have summarized the literature that describes the impact of HIE.⁹⁻¹² Using data available through 2008, Fontaine et al. noted the potential for HIE to reduce costs and improve the quality of primary care.⁹ Hincapie and Warholak conducted a review of five studies, focused on HIE outcomes, and determined that the most frequently identified outcome was utilization.¹⁰ More recently, Rudin,

et al. conducted a review focused on the United States health care system and reported that, in some instances, HIE likely reduces emergency department use and costs.¹¹ Raturkar and colleagues focused their systematic review on utilization and costs, but reported that the benefits of HIE are not yet recognized.¹² The authors of all four reviews indicated that the data are sparse and results are mixed. A larger, more comprehensive review was recently completed by our group under the auspices of the Agency for Healthcare Research and Quality (AHRQ) as part of the Evidence-based Practice Center (EPC) program.¹³ The scope of the review was international, and summarized the evidence about four HIE topics: 1) effectiveness, 2) use, 3) barriers and facilitators to use, and 4) implementation and sustainability. The results of the effectiveness,¹⁴ and barriers and facilitators¹⁵ reviews have also been published as separate manuscripts.

Objectives

This review complements our AHRQ work and two already published manuscripts,^{14,15} by calling out the identification, summarization, and synthesis of the available research specifically about the *use* of HIE.

Methods

We defined HIE as the electronic sharing of clinical information among users (clinicians, patients, administrators, or policymakers), across the boundaries of health care institutions, health data repositories, and states, typically not within a single organization or among affiliated providers, while protecting the integrity, privacy, and security of the information. We did not include the exchange of information within a single organization or entity (e.g., exchange within a network such as the Department of Veterans Affairs (VA) or exchange across roles such as patient and clinician communications within a provider organization).



The key question addressed in this review is the ‘level of use and primary uses of HIE by individuals, health care institutions or regional organizations.’ Investigator development of the key question and the PICOTS (Population, Intervention, Comparator(s), Outcomes, Timing, Setting/Study Design) framework were guided with input from key informants and members of a technical expert panel, using the formal process outlined by AHRQ.¹⁶ A standard protocol was developed and registered in PROSPERO (2014:CRD42014013285).¹⁷ The AHRQ report further describes the methods and includes search strategies and additional information.¹³

PICOTS Framework

We adopted the PICOTS framework. The study *population* included any individual or group of health care providers, patients, managers, health care institutions, or regional organizations. Studies of nonhuman subjects were excluded. The *intervention* was HIE, as implemented. Studies without original data were excluded, as were studies that modeled the potential impact of HIE or that presented, discussed, or evaluated hypothetical situations about HIE not yet implemented. *Comparators* included were time period prior to HIE implementation, different locations (geographic or organizational without HIE), situations in which HIE was not available (“usual care”), comparisons across types of HIE, and comparisons of the characteristics of the different settings, health care systems, and HIT systems in which HIE is used. As *outcomes* we captured types of data exchanged and extent of use. We also captured types of participating health care professionals and characteristics of successfully participating organizations. No pre-specified minimum duration of *time* was required between implementation of HIE and the measurement of outcomes. English-language *studies* reporting data about HIE use were included. Observational studies, qualitative research, and detailed case studies

of multiple HIE organizations were included. We included examinations both at the individual level and organizational level. Excluded were descriptive narratives or “lessons learned” essays that were not based on collecting clinical, survey, or interview data from identified users or stakeholders.

Data Sources and Searches

One research librarian conducted searches to identify relevant articles published between January 1990 and April 2015; a second reviewed the strategy. Searches were conducted in MEDLINE (Ovid), PsycINFO, CINHALL, the Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, and the National Health Sciences Economic Evaluation Database. Searches were supplemented with references identified from additional sources including reference lists of systematic reviews, table of contents of journals not indexed in databases searched, the grey literature, and experts.

Two investigators independently evaluated each study to determine inclusion eligibility. Disagreement was resolved by consensus, with a third investigator making the final decision, as needed. Details of each included study were then extracted by one investigator and again independently reviewed for accuracy and completeness by a second investigator.

Assessment of Methodological Risk of Bias of Individual Studies

The AHRQ Methods Guide for Effectiveness and Comparative Effectiveness Reviews guided our assessment of risk of bias for trials and observational studies.¹⁶ Two investigators independently assessed risk of bias. Differences were resolved by discussion and consensus. Individual studies were rated as “low,” “moderate,” or “high” risk of bias. No formal overall risk of bias rating was assigned for case studies,

mixed methods studies, studies based on computer system logs, or studies that used qualitative methods (interviews and focus groups).

Data Synthesis

Studies of HIE use could not be combined in a quantitative meta-analysis due to heterogeneity in study designs, types of HIE interventions made, metrics measured, and analytic methods applied. Therefore, data were synthesized qualitatively.

Results

Of the 5,211 abstracts identified, 58 studies met inclusion criteria (see Figure 1). A 2015 update of an ONC data brief was identified in September 2016¹⁸ and replaced the original 2014 version.

Description of Included Studies

Several methods were used by investigators to answer questions about HIE use, including surveys (25 studies),¹⁸⁻⁴² analyses of HIE audit-logs (13 studies),⁴³⁻⁵⁵ retrospective database analyses (9 studies),⁵⁶⁻⁶⁴ and mixed methods (7 studies).⁶⁵⁻⁷¹ Two studies used focus group methods,^{72,73} one study used time-motion methods,⁷⁴ and another used geo-coding.⁷⁵ Seventeen studies evaluated HIE use nationally,^{18-20,24-28,31,36,39,56-60,62} while over one-half of the studies (30 of 58) analyzed HIE implementations over a regional or statewide area.^{21-23,29,33-35,37,41-55,60,68,69,71-73,75} Separately, two studies evaluated HIE use across integrated delivery systems, both involving the VA.^{30,65} Nine studies evaluated HIE use outside of the United States,^{32,38,63,64,66,70,74} two of these in multiple countries including the United States.^{40,67}

The majority of studies evaluated HIE use across inpatient and ambulatory care settings, although eight studies were limited to evaluations of HIE use in hospitals.^{18,21,23,37,56,57,59,67}

Four of these used data from the American Hospital Association (AHA).^{18,56,57,59} Four studies 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,^{31,62} the other two using data from New York State.^{22,62} Three studies evaluated HIE use in the Emergency Department (ED); all exchanged data regionally.^{43,46,48} Two studies evaluated HIE use in office settings using data from the National Ambulatory Medical Care Survey (NAMCS);^{39,60} three others used within state data, one from Indiana,²⁹ and two from Minnesota.^{41,42} The majority of studies assessed overall use of HIE, while two assessed the use of HIE for repeated imaging in the ED,^{43,55} and two evaluated HIE for prevention or tracking of infections.^{33,37}

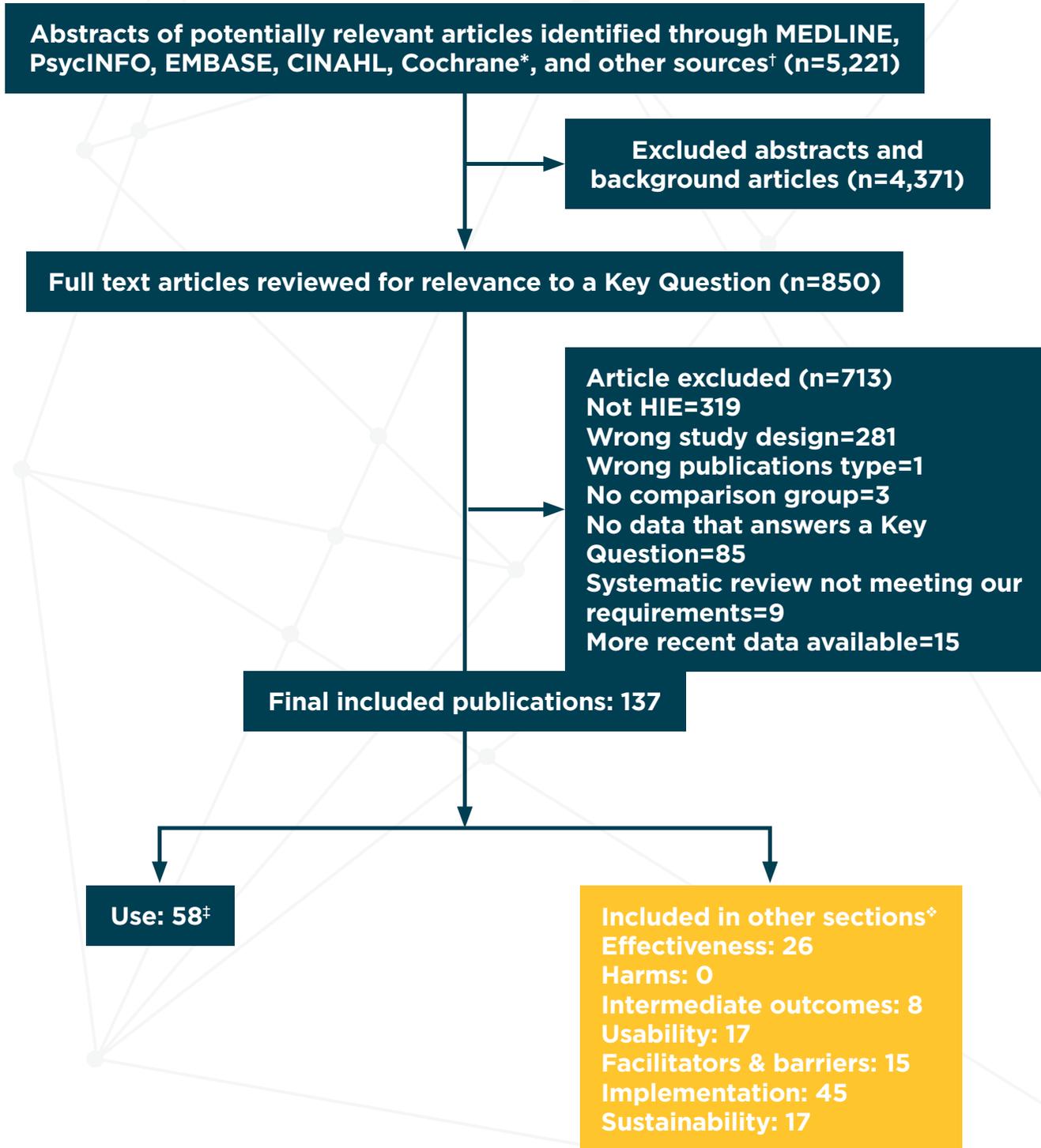
Although the majority of studies used data collected in 2009 or earlier, 27 studies included data collected in 2010 or more recently.^{18-20,22,23,28,29,31-33,37,39,40,41,44,45,49,55,57,58-62,69,73,75}

Included 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 ONC (direct, query-based, or consumer-mediated) were limited to fifteen studies wherein a specific HIE was evaluated. Of these, query-based HIE systems were noted for evaluations of the MidSouth e-Health Alliance (MSeHA),^{35,43,46,68,71} the Central Texas HIE (I-Care),⁵⁰⁻⁵⁴ the Health Care Efficiency and Affordability Law for New Yorkers Capital Grant Program (Healthcare Efficiency and Affordability Law for New Yorkers; HEAL-NY),^{44,45,56,75} and the Northeast Ohio Public Health Care System.⁶⁰ The other studies either did not specify, or multiple HIE implementations were included.

Thirty studies were rated as being at low risk of bias,^{18,21,22,24-28,31-33,35,37,39,43,48,50-60,62,66,75} eight at moderate risk of bias,^{23,29,34,40-42,61,70} and six at high risk of bias.^{36,38,63,67,69,74} The remaining studies were not rated



Figure 1. PRISMA Flow Diagram



HIE=health information exchange.

*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

◇Studies included under these sections are not discussed in this manuscript; please see the full AHRQ report for details on studies in these sections [13].

due to the type of study design (data from audit-logs or qualitative studies).

To facilitate identification of patterns of use across included studies, we have organized the results (tables) according to study design. We provide descriptions of the extent of HIE use, entities providing/viewing/accessing/receiving/exchanging data, types of data, types of personnel using HIE, whether studies met Meaningful Use criteria, characteristics of use and other notes.

U.S.-wide Surveys (Table 1 and Appendix Table A1)

Between 2006-2012, six cross-sectional surveys were conducted to investigate the frequency and types of data exchanged across U.S.-wide regional health information organizations (RHIOs), an earlier name for HIE organizations.^{24-28,36} Entities most commonly *providing* data were hospitals (83%), followed by ambulatory settings (67%). Entities most commonly *receiving* data were ambulatory settings (95%), hospitals (83%), public health departments (50%), and payers (44%).²⁴ The types of data most frequently exchanged were laboratory test results (84%-90%),^{24,25,36} inpatient data (70%), medication histories (70%), and outpatient data (60%).^{24,25} In 2008 and 2009, of 75 operational RHIOs, only 13 met the criteria for Meaningful Use criteria of the HITECH Act (3% of hospitals and <1% of ambulatory practices),²⁷ while by 2012, there had been a 61 percent increase in the number of operational RHIOs, from 75 to 119.²⁸ A 2009 study 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.³⁶

Two more recent cross-sectional surveys, conducted by the eHealth Initiative provided more recent descriptions of organizations actively exchanging data.^{19,20} These entities were a mix of community-

based, state-based, and health care delivery organizations, with no single dominant model of HIE. Hospitals and ambulatory care providers both *provided* and *viewed* data. Independent laboratories *provided* data. Community and public health clinics *viewed* data. Most HIEs took two years to become operational. By 2013, 84 organizations had reached an advanced stage of operation or innovation; 27 more had reached stages 5 (operating), 6 (sustaining), or 7 (innovating) on the eHealth Initiative's maturity scale, when compared to 2011.¹⁹ Findings in 2014 suggest an 11 percent increase over 2013 in the proportion of organizations that had reached stage 6 (operating) or higher (106 organizations).²⁰ HIE organizations are now focusing on functionalities to support health care reform initiatives and advanced analytics. 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.

Retrospective Database Analyses (Table 1 and Appendix Table A2)

Using U.S.-wide survey data collected for other purposes, nine studies used a supplemental HIT questionnaire to investigate HIE use retrospectively.^{26,38,41,55-59,61} Results from the AHA survey suggest that HIE use by hospitals has risen from 11 percent (2009)²⁵ to between 30 percent and 58 percent (2012).⁵⁷⁻⁵⁹ Results from a recently released ONC brief suggest that 82 percent of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with an outside hospital or ambulatory care provider in 2015. This represents a two-fold increase since 2008.¹⁸ Characteristics associated with higher use



Table 1. U.S.-wide Surveys, Retrospective Database Analyses, Integrated Delivery Systems

	DATA SOURCE			
	U.S.-WIDE SURVEYS (2006-2012): RHIOS ^{24-28,36}	U.S.-WIDE SURVEYS (2013-2014): EHEALTH INITIATIVE ^{19,20}	RETROSPECTIVE DATA-BASE ANALYSES ^{26,38,41,55-59,61}	TRANSFER OF RECORDS BETWEEN INTEGRATED DELIVERY SYSTEMS ^{30,65}
Extent of HIE use, by study-specific metric	Number of RHIOs: ²⁸ 2008-2009: 75 2012: 119 (61% increase) Within public health agencies (n=138) (2009): ³⁶ Exchanging information=26 (40%); No RHIO=50 (36%); No relationship with RHIO=16 (12%)	Number of organizations having reached advanced stage of operation/innovation: 2013: 8419; 2011: 57;19 2014: 10620	Number of hospitals using HIE: 2009: 11%;25 2012: 30%-58%57-59 NNHS/NSRCF: 2013: HIE use low31,62	
Entities providing data	2008: ²⁴ Hospitals: 83%; ²⁴ Ambulatory settings: 67% ²⁴	Independent laboratories; ^{19,20} Hospitals; ^{19,20} Ambulatory settings ^{19,20}		
Entities viewing/ accessing data		Hospitals; ^{19,20} Ambulatory settings; ^{19,20} Community & public health clinics ^{19,20}		
Entities receiving data	2008: 24 Ambulatory settings=95%; ²⁴ Hospitals=83%; ²⁴ Public health departments=50%; ²⁴ Payers=44% ²⁴			
Entities exchanging data			NAMCS: Majority of office-based physicians able to exchange data with other providers and hospitals (2013/2014); ^{39,60} Primary care more likely than specialists. ³⁹ NNHS/NSRCF : Of those with EHRs, 25% exchange with pharmacies; 17% with physicians. ³¹	264/363 patients (73%) were correlated across delivery systems (2011) ³⁰ N=64,237 veterans: 12%-88% of data matched between exchange partners, highest matching rates using social security numbers algorithm (2014) ⁶⁵

Note: Blank cells indicate no data available.

AHA = American Hospital Association; Lab = Laboratory; NAMCS = National Ambulatory Medical Care Survey; NNHS = National Nursing Home Survey; NSRCF = National Survey of Residential Care Facilities; ONC = Office of the National Coordinator; RHIO = regional health information organization

Table 1. U.S.-wide Surveys, Retrospective Database Analyses, Integrated Delivery Systems (Cont'd)

	DATA SOURCE			
	U.S.-WIDE SURVEYS (2006-2012): RHIOS ^{24-28,36}	U.S.-WIDE SURVEYS (2013-2014): EHEALTH INITIATIVE ^{19,20}	RETROSPECTIVE DATA-BASE ANALYSES ^{26,38,41,55-59,61}	TRANSFER OF RECORDS BETWEEN INTEGRATED DELIVERY SYSTEMS ^{30,65}
Types of data	2008 ²⁴ , 2009: ^{25,36} Laboratory test results=84%-90%; ^{24,25,36} Inpatient data=70%; ^{24,25} Medication histories=70%; ^{24,25} Outpatient data=60% ^{24,25}		ONC Brief (2015): 82% of hospitals exchanging lab results, radiology reports, clinical summaries, medication lists; 100% increase since 2008 ¹⁸	
Types of personnel using HIE				
Met Meaningful Use Criteria	2008:13/75=17% ²⁷ (3% of hospitals; <1% of ambulatory settings)			
Characteristics of Use and Other Notes		Efforts now supporting health care reform advanced analytics. Data exchange has reached stability with set of core services.	Characteristics of hospitals associated with higher use: nonprofit status; ⁵⁶⁻⁵⁹ owned by health-system; ⁵⁸ multispecialty; ⁵⁸ presence of EHR system; ⁵⁶⁻⁵⁹ larger market share; ⁵⁶⁻⁵⁹ larger practices. ⁵⁶⁻⁵⁹ Characteristics of nursing homes associated with higher use: Nonprofit status; ^{31,62} Presence of EHR system ^{31,62}	

Note: Blank cells indicate no data available.

AHA = American Hospital Association; Lab = Laboratory; NAMCS = National Ambulatory Medical Care Survey; NNHS = National Nursing Home Survey; NSRCF = National Survey of Residential Care Facilities; ONC = Office of the National Coordinator; RHIO = regional health information organization



are nonprofit status, presence of an EHR system, larger market share, and larger practices.⁵⁶⁻⁵⁹

Results from the two studies that included NAMCS data,^{39,60} suggest that the majority of office-based physicians reported being able to exchange data with other providers and hospitals. Primary care providers were more likely to use HIE than specialists.³⁹ Data from the Commonwealth Fund Health Policy Surveys describe characteristics that are associated with higher HIE use: larger practice size, practice owned by a health-system (vs. physician owned), and multispecialty (vs. single specialty) practice.⁵⁸ Data from the National Nursing Home Survey and the National Survey of Residential Care Facilities Survey indicate that HIE use in these settings is low, with the consistent pattern of nonprofit (versus for-profit) entities and facilities with EHRs enjoying wider use.^{31,62} Of those with EHRs, nearly 25 percent could exchange with pharmacies and 17 percent with physicians.³¹

Transfer of Records between Integrated Delivery Systems (Table 1 and Appendix Table A3)

The VA and Department of Defense (DoD) use the Virtual Lifetime Electronic Record (VLER) system to enable HIE with the non-federal providers, in the eHealth Exchange – a ‘network of networks.’ This is a federated, query-based model wherein users are allowed to pull in data from other organizations. In a study published in 2011, investigators studied 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.³⁰ In a larger, more recent study, 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, with the highest matching rates accomplished using social security numbers in the matching algorithm.⁶⁵

Regional or Statewide Initiatives (Table 2 and Appendix Table A4)

As part of the HITECH Act, the State Health Information Exchange Cooperative Agreement (State HIE) Program was created to achieve rapid interoperability using tailored, state-level solutions. A small number of top performing states comprise this body of literature, each reporting a different set of metrics.

Of ten studies conducted in New York,^{21-23,44,45,47,49,55,61,76} five used audit logs,^{44,45,47,49,55} with results indicating frequent queries^{44,45} and an increasing proportion of physicians accessing HIE over time (33% to 43% over 18 months).⁴⁷ Primary users varied by study, with primary users in one study being non-clinical staff in the outpatient setting and clinicians in the inpatient setting,⁴⁴ while in another, 86 percent of sessions involved staff in an ED.⁵⁵ Results of two statewide surveys of hospitals^{21,23} suggest that between 2009 and 2012 the percent of respondent hospitals participating in HIE and exchanging data, increased from 23 percent²¹ to 79 percent.²³ 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%).²³ Results of a survey of 632 nursing homes indicated that 54 percent participated 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%).²² Finally, investigators used geocoding by zip code to estimate the proportion of patients in the New York Clinical Information Exchange (now Healthix). They found that 88 percent of patients in the system live

Table 2. Regional or Statewide Initiatives

		DATA SOURCE			
		NEW YORK ^{21-23,44,45,47,49,55,61,76}	CENTRAL TEXAS HIE ⁵⁰⁻⁵⁴	MSEHA ^{35,43,46,68,71}	OTHER STATES: Indiana, ^{29,37} Minnesota, ^{41,42} Wisconsin, ³⁴ North Carolina, ⁴⁸ Northeastern Ohio, ⁶⁹ Louisiana, ⁷² Massachusetts ⁷³ (2005-2013)
Extent of HIE use, by study-specific metric	<p><u>Audit logs:</u>^{44,45,47,49,55} Frequent queries;^{44,45} Proportions of MDs accessing increased from 33% to 43% over 18 months (2012)⁴⁷</p> <p><u>Stateside surveys:</u>^{21,23} Number hospitals exchanging: 2009: 23%;²³ 2012: 79%²³</p> <p>Nursing homes, n=632): 54% participated in HIE²²</p>	<p>Hospital, public/private clinics, federally qualified health centers.</p> <p>ED use low: 57% of patients;⁵⁰ 2.3% of encounters.⁵²</p>	<p>HIE use low (2007): 12.5% of study population;⁴³ 3-10% of ED visits;⁴⁶ 15% of return ED visits;⁶⁸ 19% of return clinic visits⁶⁸</p> <p>Of 151 survey respondents/users (2011): 43% used HIE < 1 hrs/week;³⁵ 39% between 1-4 hrs/week;³⁵ 18% > 4 hrs/week³⁵</p> <p>Of 63 survey respondents for public health surveillance (2013): 50% unaware of HIE at their organization; 10% reported their organization used HIE³³</p>		
Entities providing data					
Entities viewing/ accessing data					
Entities receiving data					
Entities exchanging data	<p><u>Stateside surveys:</u>^{21,23} Hospital to hospital (71%);²³ Hospital to ambulatory care (69%);²³ Hospital to LTC (45%);²³ Hospital to Home Health (38%)²³</p> <p>Nursing homes: 31% providers exchanged outside system²²</p>				

Note: Blank cells indicate no data available.

ED = Emergency Department; Hrs = hours; Labs = Laboratory; LTC = Long term care; MSeHA = MidSouth eHealth Alliance



Table 2. Regional or Statewide Initiatives (Cont'd)

	DATA SOURCE			
	NEW YORK ^{21-23,44,45,47,49,55,61,76}	CENTRAL TEXAS HIE ⁵⁰⁻⁵⁴	MSEHA ^{35,43,46,68,71}	OTHER STATES: Indiana, ^{29,37} Minnesota, ^{41,42} Wisconsin, ³⁴ North Carolina, ⁴⁸ Northeastern Ohio, ⁶⁹ Louisiana, ⁷² Massachusetts ⁷³ (2005-2013)
Types of data	Nursing homes: Pharmacy: (42%); ²² Labs: (39%); ²² Hospital data (39%) ²²			
Types of personnel using HIE	<u>Audit logs:</u> ^{44,45,47,49,55} Primary users included non-clinical staff (outpatient) & clinicians (inpatient); ⁴⁴ 86% of sessions involved ED staff ⁵⁵	Users by decreasing frequency: ⁵⁴ Administrative > social services > physicians > nurses > public health professionals > pharmacy professionals Workplace of users: ⁵⁴ Hospital > adult ED > ambulatory care > public health agency > mental health agency > children's ED Workplace of users most frequently seeking clinical information: ⁵⁴ ED and public/mental health agencies.	HIE use higher when facilitated by nurses and clerks ^{46,68}	
Met Meaningful Use Criteria				

Note: Blank cells indicate no data available.
ED = Emergency Department; Hrs = hours; Labs = Laboratory; LTC = Long term care; MSeHA = MidSouth eHealth Alliance

Table 2. Regional or Statewide Initiatives (Cont'd)

	DATA SOURCE			
	NEW YORK ^{21-23,44,45,47,49,55,61,76}	CENTRAL TEXAS HIE ⁵⁰⁻⁵⁴	MSEHA ^{35,43,46,68,71}	OTHER STATES: Indiana, ^{29,37} Minnesota, ^{41,42} Wisconsin, ³⁴ North Carolina, ⁴⁸ Northeastern Ohio, ⁶⁹ Louisiana, ⁷² Massachusetts ⁷³ (2005-2013)
Characteristics of Use and Other Notes	Nursing homes: Characteristic of high use: has EHR ²²	HIE use higher for those with more ED visits & hospitalizations; ⁵⁰⁻⁵² older age, more chronic conditions; ^{52,54} females, those with fragmented care ⁵³ HIE use lower for Blacks & Hispanics, visits for alcohol use, injury, poisoning, an unfamiliar patient, & during a busier than average day ⁵² Study of children seen in ED: Use higher for <1year old, more frequent encounters in past, & greater number diagnoses. Use lower if the patient unfamiliar, or day busier than average. ⁵¹	HIE use occurred at various points in care. ⁷¹	Small practices not adopting HIE; ^{42,69} Larger health systems are. ^{34,41} HIE useful: In ED ^{2,9} Surveillance ^{37,48} Patients & providers view HIE favorably ^{72,73}

Note: Blank cells indicate no data available.

ED = Emergency Department; Hrs = hours; Labs = Laboratory; LTC = Long term care; MSEHA = MidSouth eHealth Alliance



within 30 minutes of New York's Times Square.⁷⁵ 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.

One group of investigators investigated HIE use in a query-based Central Texas HIE.⁵⁰⁻⁵⁴ I-Care is an HIE comprised of hospital systems, public and private clinics, and governmental agencies operating federally qualified health centers. For adult patients seen in the ED, use was low; in 57 percent of patients⁵⁰ and only 2.3 percent of encounters.⁵² 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.⁵⁴ Across these studies, HIE use was higher for those with a greater number of ED visits and hospitalizations,⁵⁰⁻⁵² older age, a greater number of chronic conditions,^{52,54} females, and those with fragmented care.⁵³ HIE use was lower for blacks and Hispanics, visits for alcohol use, injury, poisoning, an unfamiliar patient, and during a busier than average day.⁵² Similar results were found in the study that focused on children seen in the ED: use was greater for those less than one 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.⁵¹ In a companion study, 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.⁵⁴

Memphis, Tennessee, is the base for the MSeHA.^{35,43,46,68,71} In this collection of studies, in 2007,

HIE use was low, being used for 12.5 percent of the study population,⁴³ for between 3 percent and 10 percent of ED visits,⁴⁶ for 15 percent of return ED visits and 19 percent of return clinic visits.⁶⁸ In a 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.³⁵ In a workflow study, 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.⁷¹ Across these studies, use was higher when the HIE was facilitated by nurses and clerks.^{46,68} Separately, in a survey of HIE use for public health infection surveillance across six states, one-half of 63 respondents were unaware of their organization's involvement in HIE, and only 10 percent reported their organizations used HIE.³³

Finally, a collection of nine studies described HIE use in other states: Indiana,^{29,37} Minnesota,^{41,42} Wisconsin,³⁴ North Carolina,⁴⁸ Northeastern Ohio,⁶⁹ Louisiana,⁷² and Massachusetts.⁷³ These studies used data from 2005⁷³ through 2013.⁴¹ This is a disparate collection of studies wherein methods used varied widely and 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,^{42,69} while larger health systems are.^{34,41} They further suggest that HIE may be useful in exchanging data in the ED,²⁹ and for surveillance,^{37,48} 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.^{72,73}

International or Multi-National Settings (Table 3 and Appendix Table A5)

Seven studies that evaluate the use of HIE in non-U.S. settings met our inclusion criteria.^{32,38,63,64,66,70,74} Investigators in South Korea 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.³⁸ In Australia, commitment and interest in adoption increased over time,⁶³ while in Finland, a steady increase in use was seen over time by physicians, nurses and administrative staff.⁶⁴ Use in the National Health System in Scotland,⁷⁰ and in England,⁶⁶ was relatively low, although the English study is now older (2004). A study that included the 27 European Union countries plus Croatia, Iceland, Norway, and Turkey developed a metric [score between 0 (low) and 4 (high)] to measure the extent of exchange of health information, and found an average score across the 31 countries of 1.88.³²

Two multi-country studies that also included data from the United States^{40,67} comprise the last in this multinational group. Investigators found HIE adoption by physicians and hospitals in seven developed countries (United States, United Kingdom, Canada, Germany, the Netherlands, Australia, and New Zealand) to be generally low, 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.⁶⁷ In a more recent study conducted in Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Switzerland, the United Kingdom, and the United States, 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.⁴⁰ 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.

Discussion

The literature describing HIE use is quite varied, with results reported using a variety of study designs, geographic areas studied, units of analysis employed, and metrics measured. These variations made summarizing this body of literature challenging. Importantly, 30 of the 44 studies for which we were able to evaluate study quality (including surveys), were rated as having low risk of bias. We did not rate studies that used cross-sectional designs, computer system logs, or those that used qualitative methods. Indeed, the results of nationwide surveys conducted serially by the ONC,^{19,20} or by the same group of authors,^{24-28,36} and retrospective database analyses of national survey data^{26,38,41,55-59,61} were most often rated as being at low risk of bias, and therefore provide the most accurate, generalizable, and comprehensive results that can be compared over time.

What is clear from serially conducted nationwide surveys and retrospective database analyses, is that although HIE use was in its infancy worldwide in the early 2000s it has been steadily increasing since then. In the United States, in 2015, 82 percent of non-Federal acute care hospitals electronically exchanged laboratory results, radiology reports, clinical care summaries, and/or medication lists with any outside providers. This represented a doubling since 2008. There is also increasing use in ambulatory care practices, with a 2013 estimate of 38 percent of practices using HIE. Characteristics of higher HIE use are 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 lower, with the consistent pattern of nonprofits enjoying wider use than for-profit entities. Less than four in ten



Table 3. International Settings

	DATA SOURCE						
	SOUTH KOREA ³⁸	AUSTRALIA ⁶³	FINLAND ⁷⁴	FINLAND ⁶⁴	SCOTLAND ⁷⁰	ENGLAND ⁶⁶	MULTIPLE COUNTRIES
Extent of HIE use, by study-specific metric		Mean number of events uploaded per patient record: 9.7/12 mos. Number patients registered: 2007: 474; 2008: 1,320	4 of 20 diabetic visits involved HIE use	N=10 municipalities	Referrals: 18% Results reporting: 36%; Clinic email: 9%; Outpatient booking: 2% 90% respondents reported daily/weekly use		Of 27 EU countries, Denmark was highest HIE user (composite metric) (2014) ³² Use low in all 7 countries (U.S., U.K., Canada, Germany, Netherlands, Australia, New Zealand) (2008) ⁶⁷ In 10 countries (Australia, Canada, France, Germany, Netherlands, New Zealand, Norway, Switzerland, U.K., U.S.) % of primary care physicians reporting capabilities ranged from 14% (Canada) to New Zealand (55%); U.S. reported 31% (2012) ⁴⁰
Entities providing data					10% of hospital wards able to send discharge information		
Entities viewing/ accessing data					Referral system: 47%; Results reporting: 37%; Outpatient booking: 3%	Summary of care records (SCR): Accessed in 4% of encounters; Accessed in 21% of encounters, when SCR available	

Note: Blank cells indicate no data available.
EU = European Union; Lab = Laboratory

Table 3. International Settings (Cont'd)

	DATA SOURCE						
	SOUTH KOREA ³⁸	AUSTRALIA ⁶³	FINLAND ⁷⁴	FINLAND ⁶⁴	SCOTLAND ⁷⁰	ENGLAND ⁶⁶	MULTIPLE COUNTRIES
Entities receiving data							
Entities exchanging data					7% of Hospital wards able to send discharge information		
Types of data	From hospital: working diagnosis; From clinic: clinical findings; Most useful were lab results and images		1/4 visits allowed for faster treatment decision; 3/4 provided access to lab results	Viewing of reference information increased over 5 years Frequency of lab tests and imaging increased over 5 years	Lab results: 95% Referrals: 58% Discharges: 42% Outpatient booking: 16%		
Types of personnel using HIE		Nurses likely to use HIE			Clinicians used reporting/referrals; Clerical staff used discharges/bookings	Clinicians accessed 84% of time	
Met Meaningful Use Criteria							
Characteristics of Use and Other Notes						Determinants of success were clinician characteristics (not specified)	In U.S., use greater in larger practices and integrated health systems ⁴⁰

Note: Blank cells indicate no data available.
EU = European Union; Lab = Laboratory



residential care facilities that use EHRs also exchange health information.

A variety of HIE models are employed across settings. Hospitals and ambulatory care practices 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. HIE is particularly useful in the ED and in the ambulatory setting to alert providers to inpatient or ED events recently experienced by patients. Patient engagement remains low, although patients also seem willing to consent to data exchange, as long as the benefits of doing so are made clear to them.

Although many regional and statewide health-systems may have implemented HIE, few have contributed to the literature describing its use. The studies published by the health-systems that have contributed, were also rated as having low risk of bias, although the metrics evaluated fell short of providing a comprehensive picture of use. Further, they may not be generalizable. Published studies evaluate HIE use in inpatient, outpatient, community clinic, or ED settings. Results suggest that HIE is used for few patients and that the extent of HIE use is low. The formal evaluation of the State HIE Cooperative Agreement Program, conducted after project end, suggests that adoption and use varies heavily by state and that many opportunities for expansion remain.⁸ Separately, as a follow-on to their series of national surveys (included in this report), Adler-Milstein and colleagues conducted a survey of state HIE efforts, also after the end of the federally-funded program. They found that by late 2014, the number of operational HIE efforts had declined from 119 (2012) to 106,⁷⁶ raising concern about the viability and sustainability of current

approaches post-grant support. The reasons for this are many, not the least of which is competition among health-systems and EHR-vendors that offer HIE solutions. Adler-Milstein has also shown that hospitals using EHR systems provided by the dominant vendor in a marketplace engaged in an average of 45 percent more HIE activities than hospitals not using the dominant vendor.⁷⁷

Yet, regional solutions may provide one path forward, with one exemplar recently reported by the Northern California HIE Collaborative. These twelve institutions use a common EHR vendor (Epic Systems, Verona, WI) and its associated HIE platform (Care Everywhere®). Putting aside their competitive status, with the goal of improving patient care, 11 of these 12 institutions agreed to a policy of mutual querying of each other's EHR (either automated or manual), and noted a 1,349 percent increase in exchange of clinical summaries between January 2013 and February 2015.⁷⁸ Seven of these same health-systems used varying patient consent procedures for querying; those that did not require specific consent enjoyed higher levels of exchange. Noteworthy is that all participating institutions used the same EHR vendor. Further, these authors suggest that policy-level decisions that remove barriers to automatic querying and enact minimal consent procedures will likely facilitate exchange. Although increased exchange is not synonymous with improved patient outcomes, it is a necessary first step.

The results of our systematic review beg the question of whether the available literature represents the reality of HIE use in the US. The existing literature is in conflict on this issue. Results of nationwide surveys suggest increasing use, while results of statewide and regional initiatives suggest that lack of adequate funding has adversely affected sustainability. Our results provide a list of characteristics that may facilitate uptake and use of HIE. Even so, to advance our understanding of the use and impact of HIE we

suggest a coordinated effort to develop a unified framework for evaluation. Such a framework should include standardization of the description of HIE, adoption of preferred study designs, creation of an agreed-upon list of important research questions, and use of a standard set of measurement tools to facilitate comparison across health-systems.

Conclusion

The literature that describes the use of HIE nationally and globally is varied. The common theme is that HIE use has increased since the early 2000s, yet much work remains to achieve the full interoperability envisioned by the policy-makers who enacted the HITECH Act. With federal funding from state initiatives ending, states and regions are left with developing sustainability plans and policies that will enhance HIE use. Regional policies that encourage the setting aside of competition in the interest of patient care and use of a common EHR can facilitate policy-level decisions that promote information exchange may provide a path forward.

Clinical Relevance

Nationwide health information exchange is a key component of the 10-year roadmap for the United States to achieve interoperability of electronic health records by 2024. We conducted a systematic literature review to describe the use of HIE through 2015 and identified 58 studies describing either the level of use or primary uses of HIE. Use of HIE in the United States is growing but is still limited; opportunities remain for expansion to achieve interoperability by 2024.

References

1. Connecting Health and Care for the Nation: A Ten Year Vision to Achieve Interoperable Health IT Infrastructure. The Office of the National Coordinator for Health Information Technology: 2014. Available at: <https://www.healthit.gov/sites/default/files/ONC10yearInteroperabilityConceptPaper.pdf>. Accessed: August 4, 2017
2. Medicare and Medicaid electronic health record (EHR) incentive programs. Available at: <https://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/index.html?redirect=/ehrincentiveprograms>. Accessed: August 4, 2017
3. Henry J, Pylypchuk Y, Searcy T, Patel V. Adoption of Electronic Health Record Systems among U.S. Non-federal Acute Care Hospitals: 2008-2015. *ONC Data Brief*, no. 35: The Office of the National Coordinator for Health Information Technology: 2016. Available at: https://www.healthit.gov/sites/default/files/briefs/2015_hospital_adoption_db_v17.pdf. Accessed: August 4, 2017
4. Hsiao C-J, Hing E. Use and Characteristics of Electronic Health Record Systems Among Office-based Physician Practices: United States, 2001-2013. *NCHS Data Brief*, No. 143: National Center for Health Statistics: 2014. Available at: <http://www.cdc.gov/nchs/data/databriefs/db143.pdf>. Accessed: August 4, 2017
5. Jamoom EW, Yang N, Hing E. Adoption of Certified Electronic Health Record Systems and Electronic Information Sharing in Physician Offices: United States, 2013 and 2014. *NCHS Data Brief* No. 236: National Center for Health Statistics: 2016. Available at: <http://www.cdc.gov/nchs/products/databriefs/db236.htm>. Accessed: August 4, 2017
6. Connecting Health and Care for the Nation. A Shared Nationwide Interoperability Roadmap Final Version 1.0. The Office of the National Coordinator for Health Information Technology: 2014. Available at: <https://www.healthit.gov/sites/default/files/hie-interoperability/nationwide-interoperability-roadmap-final-version-1.0.pdf>. Accessed: August 4, 2017
7. What is HIE? Health IT.gov. Available at: <http://www.healthit.gov/providers-professionals/health-information-exchange/what-hie>. Accessed: August 4, 2017
8. Dullabh P, Parashuram S, Hovey L, Ubri P, Fischer K. Evaluation of the State HIE Cooperative Agreement Program. NORC at the University of Chicago. Contract Number: HHSP2337010T/OS33547. Available at: https://www.healthit.gov/sites/default/files/reports/finalsummative-report-march_2016.pdf. Accessed: August 4, 2017
9. Fontaine P, Ross SE, Zink T, Schilling LM. Systematic review of health information exchange in primary care practices. *J Am Board Fam Med* 2010;23:655-670. PMID: 20823361.
10. Hincapie A, Warholak T. The impact of health information exchange on health outcomes. *Appl Clin Inf* 2011; 2: 499-507. PMID: 23616891.
11. Rudin RS, Motala A, Goldzweig CL, Shekelle PG. Usage and effect of health information exchange: a systematic review. *Ann Intern Med*. 2014;161(11):803-11. PMID: 25437408.
12. Rahurkar S, Vest JR, Menachemi N. Despite the spread of health information exchange, there is little evidence of its impact on cost, use, and quality of care. *Health Aff (Millwood)*. 2015;34(3):477-83. PMID: 25732499.
13. Hersh W, Totten A, Eden K, Devine B, Gorman P, Kassakian S, Woods SS, Daeges M, Pappas M, McDonagh MS. Health Information Exchange. Evidence Report/Technology Assessment No. 220. (Prepared by the Pacific Northwest Evidence-based Practice Center under Contract No. 290-2012-00014-1.) AHRQ Publication No. 15(16)-E002-EF. Rockville, MD: Agency for Healthcare Research and Quality; December 2015. www.effectivehealthcare.ahrq.gov/reports/final.cfm.



14. Hersh WR, Totten AM, Eden KB, Devine B, Gorman P, Kassakian SZ, Woods SS, Daeges M, Pappas M, McDonagh MS. Outcomes From Health Information Exchange: Systematic Review. and Future Research Needs. *JMIR Med Inform* 2015;3(4):e39) doi:10.2196/medinform.5215. PMID:26678413.
15. Eden KB, Totten AM, Kassakian SZ, Gorman PN, McDonagh MS, Devine B, Pappas M, Daeges M, Woods S, WR Hersh. Barriers and facilitators to exchanging health information: a systematic review. *Int J Med Inform* 2016;88:44-51. PMID: 26878761
16. 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: <https://effectivehealthcare.ahrq.gov/ehc/products/60/318/CER-Methods-Guide-140109.pdf>. Accessed: August 4, 2017. PMID: 21433403.
17. Hersh W, Totten A, Gorman P, Eden K, Devine B, Woods S, McDonagh M, Graham E, Daegas M, Pappas M. Health information exchange. PROSPERO International prospective register of systematic reviews; number 2014:CRD42014013285. Available at: http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42014013285. Accessed: September 28, 2017
18. Patel V, Henry JW, Pylypchuk Y, Searcy T. Interoperability among U.S. Non-federal Acute Care Hospitals in 2015. *ONC Data Brief No. 36*. Washington DC. The Office of the National Coordinator for Health Information Technology (ONC), 2016. Available at: https://www.healthit.gov/sites/default/files/briefs/onc_data_brief_36_interoperability.pdf. Accessed: August 4, 2017
19. eHealth Initiative. Result from Survey on Health Data Exchange 2013. The Challenge to Connect. Available at: <https://ehi-rails-app.s3.amazonaws.com/uploads/article/file/3/eHIResultsFromSurveyonHealthDataExchange2013.pdf>. Accessed: August 4, 2017
20. eHealth Initiative. Post HITECH: The Landscape of Health Information Exchange. Available at: <http://assets.fiercemarkets.net/public/healthit/ehidataexchange2014.pdf>. Accessed: August 4, 2017
21. Abramson EL, McGinnis S, Edwards A, Maniccia DM, Moore J, Kaushal R; HITEC investigators. 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.
22. Abramson EL, McGinnis S, Moore J, Kaushal R; HITEC investigators. A statewide assessment of electronic health record adoption and health information exchange among nursing homes. *Health Serv Res*. 2014;49(1 Pt 2):361-72. PMID: 24359612.
23. Abramson EL, Silver M, Kaushal R. Meaningful use status and participation in health information exchange among New York State hospitals: A longitudinal assessment. *Jt Comm J Qual Patient Saf*. 2014;40(10). PMID: 26111305.
24. Adler-Milstein J, McAfee AP, Bates DW, Jha AK. The state of regional health information organizations: current activities and financing. *Health Aff*. 2008;27(1):w60-9. PMID: 18073225.
25. Adler-Milstein J, Bates DW, Jha AK. U.S. Regional health information organizations: progress and challenges. *Health Aff*. 2009;28(2):483-92. PMID: 19276008.
26. Adler-Milstein J, Landefeld J, Jha AK. Characteristics associated with regional health information organization viability. *J Am Med Inform Assoc*. 2010;17(1):61-5. PMID: 20064803.
27. Adler-Milstein J, Bates DW, Jha AK. A survey of health information exchange organizations in the United States: implications for meaningful use. *Ann Intern Med*. 2011;154(10):666-71. PMID: 21576534.
28. Adler-Milstein J, Bates DW, Jha AK. Operational health information exchanges show substantial growth, but long-term funding remains a concern. *Health Aff (Millwood)*. 2013;32(8):1486-92. PMID: 23840051.
29. Anand V, Sheley ME, Xu, S, Downs SM. Real time alert system: a disease management system leveraging health information exchange. *Online J Public Health Inform*. 2012;4(3) PMID: 23569648.
30. Bouhaddou O, Bennett J, Cromwell T, Nixon G, Teal J, Davis M, Smith R, Fischetti L, Parker D, Gillen Z, Mattison J. The Department of Veterans Affairs, Department of Defense, and Kaiser Permanente Nationwide Health Information Network exchange in San Diego: patient selection, consent, and identity matching. *AMIA Annu Symp Proc*. 2011;2011:135-43. PMID: 22195064.
31. Caffrey C, Park-Lee E. Use of electronic health records in residential care communities. *NCHS data brief*. 2013(128):1-8. PMID: 24152578.
32. Codagnone C, Lupiallez-Villanueva F. Benchmarking Deployment of eHealth among General Practitioners (2013) - Final Report. Luxembourg: European Commission.
33. Dixon BE, McGowan JJ, Grannis SJ. Electronic laboratory data quality and the value of a health information exchange to support public health reporting processes. *AMIA Annu Symp Proc*. 2011;2011:322-30. PMID: 22195084.
34. Foldy S. Inventory of electronic health information exchange in Wisconsin, 2006. *WMJ*. 2007;106(3):120-5. PMID: 17642349.
35. Gadd CS, Ho Y-X, Cala CM, Blakemore D, Chen Q, Frisse ME, Johnson KB. User perspectives on the usability of a regional health information exchange. *J Am Med Inform Assoc*. 2011;18(5):711-6. PMID: 21622933.
36. Hessler BJ, Soper P, Bondy J, Hanes P, Davidson A. Assessing the relationship between health information exchanges and public health agencies. *J Public Health Manag Pract*. 2009;15(5):416-24. PMID: 19704310.
37. Kho AN, Doebbeling BN, Cashy JP, Rosenman MB, Dexter PR, Shepherd DC, Lemmon L, Teal E, Khokar S, Overhage JM. A regional informatics platform for coordinated antibiotic-resistant infection tracking, alerting, and prevention. *Clin Infect Dis*. 2013;57(2):254-62. PMID: 23575195.
38. Lee S-I, Park H, Kim J-W, Hwang H, Cho EY, Kim Y, Ha K. Physicians' perceptions and use of a health information exchange: a pilot program in South Korea. *Telemed J E Health*. 2012;18(8):604-12. PMID: 22352898.
39. Patel V, Swain MJ, King J, Furukawa MF. Physician capability to electronically exchange clinical information, 2011. *Am J Manag Care*. 2013;19(10):835-43. PMID: 24304162.

40. Schoen C, Osborn R, Squires D, Doty M, Rasmussen P, Pierson R, Applebaum S. A survey of primary care doctors in ten countries shows progress in use of health information technology, less in other areas. *Health Aff (Millwood)*. 2012;31(12):2805-16. PMID: 23154997.
41. Soderberg K, Laventure M. Minnesota clinics' adoption, use and exchange of electronic health information. *Minn Med*. 2013;96(9):45-8. PMID: 24494362.
42. Fontaine P, Zink T, Boyle RG, Kralewski J. Health information exchange: participation by Minnesota primary care practices. *Arch Intern Med*. 2010;170(7):622-9. PMID: 20386006.
43. Bailey JE, Pope RA, Elliott EC, Wan JY, Waters TM, Frisse ME. Health information exchange reduces repeated diagnostic imaging for back pain. *Ann Emerg Med*. 2013;62(1):16-24. PMID: 23465552.
44. Campion TR, Jr., Edwards AM, Johnson SB, Kaushal R; HITEC investigators. Health information exchange system usage patterns in three communities: practice sites, users, patients, and data. *Int J Med Inf*. 2013;82(9):810-20. PMID: 23743323.
45. Campion TR, Jr., Vest JR, Ancker JS, Kaushal R3; HITEC Investigators. Patient encounters and care transitions in one community supported by automated query-based health information exchange. *AMIA Annu Symp Proc*. 2013;2013:175-84. PMID: 24551330.
46. Johnson KB, Gadd CS, Aronsky D, Yang K, Tang L, Estrin V, King JK, Frisse M. The MidSouth eHealth Alliance: use and impact in the first year. *AMIA Annu Symp Proc*. 2008:333-7. PMID: 18999184.
47. Kern LM, Ancker JS, Abramson E, Patel V, Dhopeswarkar RV, Kaushal R. Evaluating health information technology in community-based settings: lessons learned. *J Am Med Inform Assoc*. 2011;18(6):749-53. PMID: 21807649.
48. Lobach DF, Kawamoto K, Anstrom KJ, Kooy KR, Eisenstein EL, Silvey GM, Willis JM, Johnson F, Simo J. Proactive population health management in the context of a regional health information exchange using standards-based decision support. *AMIA Annu Symp Proc*. 2007:473-7. PMID: 18693881.
49. Moore T, Shapiro JS, Doles L, Calman N, Camhi E, Check T, Onyile A, Kuperman G. Event detection: a clinical notification service on a health information exchange platform. *AMIA Annu Symp Proc*. 2012;2012:635-42. PMID: 23304336.
50. Vest JR. Health information exchange and healthcare utilization. *J Med Syst*. 2009;33(3):223-31. PMID: 19408456.
51. Vest JR, Jasperson JS, Zhao H, Gamm LD, Ohsfeldt RL. Use of a health information exchange system in the emergency care of children. *BMC Med Inform Decis Mak*. 2011;11:78. PMID: 22208182.
52. Vest JR, Zhao H, Jasperson J, Gamm LD, Ohsfeldt RL. Factors motivating and affecting health information exchange usage. *J Am Med Inform Assoc*. 2011;18(2):143-9. PMID: 21262919.
53. Vest JR, Gamm LD, Ohsfeldt RL, Zhao H, Jasperson JS. Factors associated with health information exchange system usage in a safety-net ambulatory care clinic setting. *J Med Syst*. 2012;36(4):2455-61. PMID: 21523428.
54. Vest JR, Jasperson JS. How are health professionals using health information exchange systems? Measuring usage for evaluation and system improvement. *J Med Syst*. 2012;36(5):3195-204. PMID: 22127521.
55. Vest JR, Grinspan ZM, Kern LM, Campion TR Jr, Kaushal R; HITEC Investigators. Using a health information exchange system for imaging information: patterns and predictors. *AMIA Annu Symp Proc*. 2013;2013:1402-11. PMID: 24551416.
56. Adler-Milstein J, DesRoches CM, Jha AK. Health information exchange among U.S. hospitals. *Am J Manag Care*. 2011;17(11):761-8. PMID: 22084896.
57. Adler-Milstein J, Jha AK. Health information exchange among U.S. hospitals: Who's in, who's out, and why? *Healthcare*. 2014;2(1):26-32. PMID: 26250086.
58. Audet A-M, Squires D, Doty MM. Where are we on the diffusion curve? Trends and drivers of primary care physicians' use of health information technology. *Health Serv Res*. 2014;49(1 Pt 2):347-60. PMID: 24358958.
59. Furukawa MF, Patel V, Charles D, Swain M, Mostashari F. Hospital Electronic Health Information Exchange Grew Substantially In 2008-12. *Health Aff*. 2013;32(8):1346-54. PMID: 23918477.
60. Furukawa MF, King J, Patel V, Hsiao CJ, Adler-Milstein J, Jha AK. Despite Substantial Progress In EHR Adoption, Health Information Exchange And Patient Engagement Remain Low In Office Settings. *Health Aff*. 2014:1-8. PMID: 25104827.
61. Gutteridge DL, Genes N, Hwang U, Kaplan B; GEDI WISE Investigators, Shapiro JS. Enhancing a Geriatric Emergency Department Care Coordination Intervention Using Automated Health Information Exchange-Based Clinical Event Notifications. *eGEMS (Wash DC)*. 2014;2(3)
62. Hamann DJ, Bezboruah KC. Utilization of technology by long-term care providers: comparisons between for-profit and nonprofit institutions. *J Aging Health*. 2013;25(4):535-54. PMID: 23509114.
63. Silvester BV, Carr SJ. A shared electronic health record: lessons from the coalface. *Med J Aust*. 2009;190(11 Suppl):S113-6. PMID: 19485857.
64. Mäenpää T, Asikainen P, Gissler M, Siponen K, Maass M, Saranto K, Suominen T. The utilization rate of the regional health information exchange: how it impacts on health care delivery outcomes. *J Public Health Manag Pract*. 2012;18(3):215-23. PMID: 22473113.
65. Byrne CM, Mercincavage LM, Bouhaddou O, Bennett JR, Pan EC, Botts NE, Olinger LM, Hunolt E, Banty KH, Cromwell T. The Department of Veterans Affairs' (VA) implementation of the Virtual Lifetime Electronic Record (VLER): Findings and lessons learned from Health Information Exchange at 12 sites. *Int J Med Inf*. 2014;83(8):537-47. PMID: 24845146.
66. Greenhalgh T, Stramer K, Bratan T, Byrne E, Russell J, Potts HW. Adoption and non-adoption of a shared electronic summary record in England: a mixed-method case study. *BMJ*. 2010;340:c3111. PMID: 20554687.
67. Jha AK, Doolan D, Grandt D, Scott T, Bates DW. The use of health information technology in seven nations. *Int J Med Inf*. 2008;77(12):848-54. PMID: 18657471.
68. Johnson KB, Unertl KM, Chen Q, Lorenzi NM, Nian H, Bailey J, Frisse M. Health information exchange usage in emergency departments and clinics: the who, what, and why. *J Am Med Inform Assoc*. 2011;18(5):690-7. PMID: 21846788.



69. Kaelber DC, Waheed R, Einstadter D, Love TE, Cebul RD. Use and perceived value of health information exchange: one public healthcare system's experience. *Am J Manag Care*. 2013;19(10 Spec No):Sp337-43. PMID: 2451888.
70. Pagliari C, Gilmour M, Sullivan F. Electronic Clinical Communications Implementation (ECCI) in Scotland: a mixed-methods programme evaluation. *J Eval Clin Pract*. 2004;10(1):11-20. PMID: 14731147.
71. Unertl KM, Johnson KB, Lorenzi NM. Health information exchange technology on the front lines of healthcare: workflow factors and patterns of use. *J Am Med Inform Assoc*. 2012;19(3):392-400. PMID: 22003156.
72. Herwehe J, Wilbright W, Abrams A, Bergson S, Foxhood J, Kaiser M, Smith L, Xiao K, Zapata A, Magnus M. Implementation of an innovative, integrated electronic medical record (EMR) and public health information exchange for HIV/AIDS. *J Am Med Inform Assoc*. 2012;19(3):448-52. PMID: 22037891.
73. Tripathi M, Delano D, Lund B, Rudolph L. Engaging patients for health information exchange. *Health Aff*. 2009;28(2):435-43. PMID: 19276000.
74. Maass MC, Asikainen P, Mäenpää T, Wanne O, Suominen T. Usefulness of a Regional Health Care Information System in primary care. A case study. *Comput Methods Programs Biomed*. 2008;91(2):175-81. PMID: 18514363.
75. Onyile A, Vaidya SR, Kuperman G, Shapiro JS. Geographical distribution of patients visiting a health information exchange in New York City. *J Am Med Inform Assoc*. 2013;20(e1):e125-30. PMID: 23104049.
76. Adler-Milstein J, Lin SC, Jha AK. The number of health information exchange efforts is declining, leaving the viability of broad clinical data exchange uncertain. *Health Aff* 2016;35:1278-1285. PMID: 27385245.
77. Everson J, Adler-Milstein J. Engagement in hospital health information exchange is associated with vendor marketplace dominance. *Health Aff* 2016;35:1286-1293. PMID: 27385246.
78. Downing NL, Adler-Milstein J, Palma JP, Lane S, Eisenberg M, Sharp C, Northern California HIE Collaborative, Longhurst CA. Health information exchange policies of 11 diverse health systems and the associated impact on volume of exchange. *J Am Med Inform Assoc* 2016 Jun 14. pii: ocw063. doi: 10.1093/jamia/ocw063. PMID: 27301748.

Appendix. Supplemental Tables

Please use the following link to download a PDF of the supplemental tables:

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