
Clinical Value-Add for Health Information Exchange (HIE)

J Joshi

Citation

J Joshi. *Clinical Value-Add for Health Information Exchange (HIE)*. The Internet Journal of Medical Informatics. 2010 Volume 6 Number 1.

Abstract

Objectives: We describe the clinical utility- both positive and negative- of Health Information Exchanges (HIE) in order to ascertain how true value can be attained through the adoption of such a system. **Methods:** We performed a literature review over multiple databases of 350 articles pertaining to the topic. After screening for relevance, we selected 135 articles that discuss studies pertaining to HIE. **Results:** We populated two tables with information synthesized from the 135 journal articles. One table focuses on the positive aspects of HIE, and the second table focuses on the negative aspects of HIE. Our focus is to highlight clear benefits, notable uncertainties, and position them in juxtapose to establish a clear comparison. **Conclusions:** Though HIE have both positive and negative aspects, one must focus on the specificities of the health institution, including patient volume, demographics, and health focus, in order to determine the value of implementing such a system.

INTRODUCTION

Health Information Exchanges (HIE) are rapidly advancing as the next step in improving patient care using technological applications. HIE affect the fundamental patient care system by transforming how medical information is delivered and disseminated. Medicine in America has long been a fragmented field; and with the ever increasing amount of transactional volume of patient information, the need to integrate the system in a coherent manner becomes all the more imperative. However, intuitive benefits of such a system belie inherent risks in creating such a system. Adapting a large scale HIE creates logistical and patient safety related problems. Numerous government and private organizations have developed studies or simulations detailing both the positive and negative aspects of HIE. Published studies that demonstrate seemingly apparent benefits are often limited in nature and contingently specific. We perform a systematic review of the literature and present the information to obtain a comprehensive view of how truly effective HIE can be. We focus our review on the clinical implications of HIE systems.

From the available data, we extrapolate key parameters to construct a value-added table highlighting the benefits and risks or uncertainties of a HIE. We focus on those attributes which affect patient management, influence physician decision-making, and impact both short-term and long-term decision analyses.

METHODS

We performed an indexed internet search using the following search engines: PubMed, Cochrane Database, and Google scholar. The searches took place June, July, August, and October of 2010. We began with the phrase, "Health Information Exchange (HIE)", and broadened the search terminology to include similar terminology associated with HIE, thus maximizing sensitivity. We reviewed the literature directly addressing studies and surveys conducted on the topic. Sources include independent consultant reviews, academic journals, and articles detailing academic based HIE initiatives. Our search catered to broad based studies pertinent to the general patient population, and not any specialty specific study. Although we did not distinguish set criteria for what constitutes our targeted practice, we took aims to distinguish the scope of each study to better assess its applicability in reflecting general populations.

Studies were mostly taken from academic published journals available through the search engines. However, a few private, consulting based studies were included in the study, but denoted as such.

Data was extracted from the study, synthesized, and integrated into descriptive excerpts detailing key points. We populated the data within a two dimensional matrix highlighting key clinical parameters. Clinical parameters and the associated benefits included are commonly accepted metrics used to gauge improvements upon implementing

EMR/EHR.¹ A literature search and expert review at the Chicago Health Information Technology Regional Extension Center (CHITREC) helped establish the framework of the matrix. The clinical parameters include lab results, medications, prescriptions, previous outpatient visits, emergency visits, current ambulatory outpatient visits, quality of notes, long term benefits, time efficiency, and diagnoses. The benefits associated include quality of care, effect of patients, cost savings to physicians, error reduction, and organizational efficiency and regulatory compliance. Two parallel dimensional matrices were created in which one highlighted the positive aspects of HIE and the other highlighted the negative aspects.

The studies were then classified based on the nature of the article, and the material covered. We first divided each study into either a qualitative or quantitative study. Quantitative studies include any study formatted as a hypothesis testing study, cross sectional study, or predictive analysis. All classification schemes and syntheses were developed internally.

We then abstracted the relevant data from the articles using narrative synthesis. In synthesizing the articles, we reviewed the nature of the article, and the nature of the HIE discussed. We identified studies on mostly generalist based systems, emergency system only systems, and rarely specialty based systems. We found significant overlap amongst the many articles. While most qualitative, and some quantitative, studies reviewed the entire HIE system, some focused on a particular aspect. We noted what aspect was highlighted in the study accordingly. Many HIE range in geographic and demographic scope. Those exchange centers that were studied within a limited context were distinguished from those that encompassed all patients within the HIE.

Since few of the studies were quantitative in nature, it became difficult to analyze them through a standard meta-analysis. We abstracted details in select studies and identified themes within each publication. The themes formed the basis of the value-added graph allowing the concepts from each publication to organically flow into the two dimensional table.

There are no funding sources to disclose at any point in our data collection.

RESULTS

Of the nearly 350 studies reviewed, we included 135 studies. The relatively high rate of inclusion is largely due to the

nature of the review and the assistance of established review studies that guided our literature review. Inclusion criteria included a specific mentioning of HIE and RHIO, or the transition of EHR and EMR to HIE. Further inclusion criteria includes any mentioning of HIE research, applicability, prominent obstacles, or inherent limitations. Of the studies compiled that met all the inclusion criteria 18% (24/135) were quantitative in nature. Of the study methods, 7% (10/135) only primary surveys, 28% (38/135) were editorial in nature, 47% (64/135) were informational in nature, 2% (3/135) conducted interviews, and 10% (14/135) were review articles. One study ran a simulation, and another study exemplified various business models applicable to a HIE. The majority claimed to be broad in scope and to represent that typical patient community. In our study, we find that 73% (98/135) maintain a broad scope. The remaining studies either specified a geographic scope or a particular clinical focus.

We did not distinguish between open and closed exchange systems since most new models considering adopting HIE are open models. However, for certain cases, such as emergency departments, we included only community based studies, therefore accepting only open based systems. This arrangement better suited our study's focus in developing generalizations for sustainable competitive advantage. Of the studies that met the inclusion criteria, 21% (28/135) focused on primary operations of an HIE, 3% (4/135) exclusively on emergency departments in community hospitals, 2% (2/135) on the financial aspects of HIE, 5% (6/135) on only patient safety and privacy, 2% (2/135) on HIV patient safety, 3% (3/135) on long term continuity of care, 11% (15/135) on the transition between electronic records and a viable exchange model, 4% (6/135) on improving adoption rates among hospitals, 3% (4/135) on utilizing standardizations, 4% (5/135) on improving cost effectiveness of HIE, and 2% (3/135) on developing a national scale model.

After cataloguing our studies, we integrated each study into our value-added table.

Figure 1
Table 1

	Lab Results	Medications	Prescriptions	Previous and Repeat Visits to other Physicians	Emergency Visits	Ambulatory Visits	Quality of Overall Notes	Lung Term Benefits	Time Efficiency	Diagnosis
Positive										
Quality of Care	Information from other institutions prior lab results and insurance bills and reduce the risk of missing laboratory results	More parallelly improve medication compliance, reduce duplicate medications, reduce interactions, and reduce drug costs	More than 10% of patients' prescriptions are not filled	Interim reports to avoid repeating of tests and certain infectious diseases more efficient and complete	Emergency department has a percentage of patients with information available during admission and lower percentage of emergency department visits	Increase awareness of guidelines or protocols, increase efficiency of implementation, when physicians	Customizable templates and specific functional capabilities to increase efficiency of implementation, when physicians	Summed up, patients are willing to share their health information and use it to make decisions about their health care	Physicians reduced operational costs and have to leave for the waiting list for other patients	State funded HIE programs are subject to public access and publication of records for other patients
Effect on Patients	Instantly available, allowing data to change in real time, the data is available in meaningful and useful checks	Patients receive more coordinated care, the patient information and medication history are available	Patients' medication compliance is improved, the number of generic prescriptions is reduced	Patients' medication compliance is improved, the number of generic prescriptions is reduced	HIE reduces the number of emergency department visits and the number of repeat visits to the health system	Patients' medication compliance is improved, the number of generic prescriptions is reduced	Patients on average have a higher percentage of ambulatory visits and lower percentage of emergency department visits	All patients receive the same information and advice, and the information is available to all patients	HIE patients reduced the number of repeat visits to the health system	Patients prefer not to repeat medical tests and reducing the responsibility to that medical practice
Cost Saving to Physician	Publicly available, allowing data to change in real time, the data is available in meaningful and useful checks	HIE cost is not significant, the HIE cost is not significant, the HIE cost is not significant	Significant cost savings are realized, the HIE cost is not significant	Realistic cost savings are realized, the HIE cost is not significant	Minor reductions in the number of emergency department visits and the number of repeat visits to the health system	The HIE reduces the number of emergency department visits and the number of repeat visits to the health system	More cost-effective, the HIE reduces the number of emergency department visits and the number of repeat visits to the health system	HIE patients reduced the number of repeat visits to the health system	Physicians' medication compliance is improved, the number of generic prescriptions is reduced	Multi-institutional HIE programs are subject to public access and publication of records for other patients
Error Reduction	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	HIE reduces the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	Operational HIEs reduce the number of errors, the HIE reduces the number of errors	HIE reduces the number of errors, the HIE reduces the number of errors
Organizational Efficiency and Regulatory Compliance	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems	HIEs are subject to the same level of compliance as existing systems

DISCUSSION

Our table suggests that the context by which we gauge each clinical parameter determines the net benefit or downside. The benefits reaped from organizing emergency visits through an electronic exchange quickly fade when viewed from the perspective of the physicians themselves. The potential benefit of recording infection rates nationally become markedly more pronounced as the marginal size of the exchange system decreases. The intricacies of geographic scope of scale add another dimension that further complicates understanding all of the benefits. While certain articles note clear benefits in more closed, homogenous patient populations, it is not clear how those benefits translate to larger health institutions. This is not to say that large clinics do not contain unique benefits in and of themselves. The established literature and prior studies attest to the unique benefits of each system. In our tables, we attempt to capitalize on the general principles that construe benefits and downsides in each clinical parameter per the vantage point of the clinicians.

Since our goal is to determine what principles can be generalized to all HIE inclusive of size, scale or scope, our contribution lies in identifying the clinical parameters in parallel. This discrete format demonstrates that no one parameter can be ubiquitously assigned as a benefit or downside.

Figure 2
Table 2

	Lab Results	Medications	Prescriptions	Previous and Repeat Visits to other Physicians	Emergency Visits	Ambulatory Visits	Quality of Overall Notes	Lung Term Benefits	Time Efficiency	Diagnosis
Negative										
Quality of Care	True benefits from integrating HIE to results are not always dependent on the accuracy of data entry	Medication data on HIE is subject to the same level of accuracy as existing systems	Adverse drug events that are truly dependent on the accuracy of data entry	Limitations in HIE data require the patient to repeat information in order to begin treatment, this may result in a delay in care	Many emergency department visits are due to the lack of information available in the HIE	Patients' medication compliance is improved, the number of generic prescriptions is reduced	Physicians' medication compliance is improved, the number of generic prescriptions is reduced	Physicians' medication compliance is improved, the number of generic prescriptions is reduced	Physicians' medication compliance is improved, the number of generic prescriptions is reduced	The utility of HIE is dependent on the accuracy of data entry
Effect on Patients	Lab results that affect patient management are already available in established patient portals that HIE may improve report	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	The same information is available in the HIE as in the patient portal
Cost Saving to Physician	The calculated net savings may be high, but the cost of implementation and maintenance may be high	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	Placing medication orders on HIE requires a relatively complex and costly system, which may not be cost-effective	HIE are limited by the same factors as existing systems
Error Reduction	HIE is prone to increase errors by both improving the accuracy and reducing the number of errors	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	Due to many challenges in integrating HIE, many patients are unable to access their medication information	In all physicians prefer to use HIE for information gathering, more than data interpretation, hence data is a major benefit of HIE
Organizational Efficiency and Regulatory Compliance	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	All HIEs maintain the same level of compliance as existing systems	It is assumed that the regulatory requirements are the same for all HIEs

Our value-added proposition implies we turn towards a more nuanced understanding of an HIE's competitive advantage. A sustainable competitive advantage is the ability to provide a service to the target consumer in a manner that an alternative option cannot. To identify true benefits, one must determine what additional benefits an HIE would provide within a specific context. For instance, will the target consumer be government organizations instituting a system that hospital systems buy into? Or will the target consumer be smaller practice groups that are sought after by larger academic or insurance based systems? These questions affect the scope and viability of HIE.

While many of the benefits of HIE can be countered with legitimate uncertainties, one should not discount the burgeoning potential of these systems. Disruptive innovations, which HIE's propose to become in today's healthcare, have the ability to convert seemingly low value solutions into viable options that become the optimal path. In a field such as information technology exchange, network externalities play an immense role in creating consumer

awareness and increasing the value of the technology. Many uncertainties are influenced by the physician's willingness to adopt or accept the role of HIE. Increased implementation by physicians will have a positive exponential effect and mitigate such uncertainties.

Research into the field should be inventive and bold. With such a complex concept involving innumerable variables, it is not likely to be solved without many prior attempts. Beyond finding an optimal operational model for HIE, experimentation will identify why concepts have not worked in the past.

Limitations in this study include the methods of collection to the overall analysis, and the data abstraction. We were unable to perform a meta-analysis of the available literature because few of them were quantitative in nature. Further majority of the studies pertaining to this topic are subject to journalistic bias. The authors, predominantly leaders in the field, have certain perspectives on how an exchange system should run. Abstracting a narrative synthesis from their vantage point provides only a portion of the functionality relating to HIE.

Additionally, our search was limited to the strength of the terminology we used for our literature search. Key terms such as "Health Information Exchange" may not adequately encompass all the literature available on the subject. We avoided this error in part by cross referencing our literature review with established literature searches to ensure comprehensiveness. However, those journal articles referencing HIE with unique terminology or case specific phrases are likely to have been missed. We also limited our search to English-based studies and included only a limited number of unique search engines to further our literature review.

ACKNOWLEDGEMENTS

We would like to acknowledge Dr. Abel Kho of the Chicago Health Information Technology Regional Extension Center (CHITREC) and Northwestern University for their contribution, expertise, and advice during the data collection and interpretation process.

References

1. "The State of Health Information Exchange in 2010:." A Report Based on the Results of the EHealth Initiative's 2010. EHealth Initiative, 2010. Web. 27 Sept. 2010. <http://www.ehealthinitiative.org/uploads/file/Final%20Report.pdf>.
2. Sutton M, Anthony MN, Vila C, McLellan-Lemal E, Weidle PJ. HIV testing and HIV/AIDS treatment services in rural counties in 10 southern states: service provider perspectives. *J Rural Health*. 2010 Jun;26(3):240-7.
3. Mark F. Health Information Exchange in Memphis: Impact on the Physician- Patient Relationship. *The Journal of Law, Medicine & Ethics*. Volume 38 Issue 1. March 26, 2010.
4. Committee on Quality of Health Care in America. *Crossing the Quality Chasm: A New Health System for the 21st Century*. Institute of Medicine (IOM). 2001
5. McClellan M, McGinnis M, Nabel E, Olsen LM. *Evidence-Based Medicine and the Changing Nature of Health Care*. Institute of Medicine of the National Academics. 2007 IOM Annual Meeting. The National Academic Press.
6. Committee on the Health Professions Education Summit. Editors; Greiner A, Knebel E. *Health Professions Education: A Bridge to Quality*. Institute of Medicine. The National Academic Press. Washington DC. 2003
7. Fontaine P, Ross SE, Zink T, Schilling LM. Systematic review of health information exchange in primary care practices. *J Am Board Fam Med*. 2010 Sep-Oct;23(5):655-70.
8. Proeschold-Bell RJ, Belden CM, Parnell H, Cohen S, Cromwell M, Lombard F. A randomized controlled trial of health information exchange between human immunodeficiency virus institutions. *J Public Health Manag Pract*. 2010 Nov-Dec;16(6):521-8.
9. Downs SM, van Dyck PC, Rinaldo P, McDonald C, Howell RR, Zuckerman A, Downing G. Improving newborn screening laboratory test ordering and result reporting using health information exchange. *J Am Med Inform Assoc*. 2010 Jan-Feb;17(1):13-8.
10. Vest JR, Gamm LD. Health information exchange: persistent challenges and new strategies. *J Am Med Inform Assoc*. 2010 May 1;17(3):288-94.
11. Foy R, Hempel S, Rubenstein L, Suttrop M, Seelig M, Shanman R, Shekelle PG. Meta-analysis: effect of interactive communication between collaborating primary care physicians and specialists. *Ann Intern Med*. 2010 Feb 16;152(4):247-58.
12. DesRoches CM, Campbell EG, Vogeli C, Zheng J, Rao SR, Shields AE, Donelan K, Rosenbaum S, Bristol SJ, Jha AK. Electronic health records' limited successes suggest more targeted uses. *Health Aff (Millwood)*. 2010 Apr;29(4):639-46.
13. Hinman AR, Ross DA. Immunization registries can be building blocks for national health information systems. *Health Aff (Millwood)*. 2010 Apr;29(4):676-82.
14. Goldstein AM. The Effects of Health Information Technology on the Physician Patient Relationship: Health Information Technology and the Idea of Informed Consent. *Journal of Law, Medicine, and Ethics*. 2010
15. Frisse ME. Health information exchange in Memphis: impact on the physician-patient relationship. *J Law Med Ethics*. 2010 Spring;38(1):50-7.
16. Frisse ME. The Effects of Health Information Technology on the Physician-Patient Relationship: Health Information Exchange in Memphis: Impact on the Physician-Patient Relationship. *Journal of Law, Medicine, and Ethics*. Spring 2010.
17. Overhage JM, Evans L, Marchibroda J. Communities' readiness for health information exchange: the National Landscape in 2004. *J Am Med Inform Assoc*. 2005 Mar-Apr;12(2):107-12. Epub 2004 Nov 23
18. Mandl K, Kohane I. Tectonic Shifts in the Health Information Economy. *N Engl J Med* 2008; 358:1732-1737
19. Blumenthal D, Glaser J. Information Technology Comes to Medicine. *N Engl J Med* 2007; 356:2527-2534

20. McGraw D, Dempsey JX, Harris L, Goldman J. Privacy as an enabler, not an impediment: building trust into health information exchange. *Health Aff (Millwood)*. 2009 Mar-Apr;28(2):416-27.
21. Gandhi TK, Weingart SN, Seger AC, Borus J, Burdick E, Poon EG, Leape LL, Bates DW. Outpatient prescribing errors and the impact of computerized prescribing. *J Gen Intern Med*. 2005 Sep;20(9):837-41.
22. Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R, and Taylor R, "Can Electronic Medical Record Systems Transform Healthcare? An Assessment of Potential Health Benefits, Savings, and Costs," *Health Affairs*, Vol. 24, No. 5, September 14, 2005.
23. Gans D, Kralewski J, Hammons T, Dowd B. Medical groups' adoption of electronic health records and information systems. *Health Aff (Millwood)*. 2005 Sep-Oct;24(5):1323-33.
24. Heyman J. Health IT and solo practice: a love-hate relationship. *J Law Med Ethics*. 2010 Spring;38(1):14-6.
25. Wensing M, van Lieshout J, Koetsenruiter J, Reeves D. Information exchange networks for chronic illness care in primary care practices: an observational study. *Implement Sci*. 2010 Jan 22;5:3.
26. Overhage JM, Grannis S, McDonald CJ. A comparison of the completeness and timeliness of automated electronic laboratory reporting and spontaneous reporting of notifiable conditions. *Am J Public Health*. 2008 Feb;98(2):344-50. Epub 2008 Jan 2.
27. Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, Morton SC, Shekelle PG. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Ann Intern Med*. 2006 May 16;144(10):742-52. Epub 2006 Apr 11.
28. Walker J, Pan E, Johnston D, Adler-Milstein J, Bates D, Middleton B. The Value of Health Care Information Exchange and Interoperability. *Health Affairs*. January 19, 2005.
29. Hook JM, Pan E, Adler-Milstein J, Bu D, Walker J. The value of healthcare information exchange and interoperability in New York state. *AMIA Annu Symp Proc*. 2006:953.
30. Cotter CM. Making the case for a clinical information system: the chief information officer view. *J Crit Care*. 2007 Mar;22(1):56-65.
31. Doyle TJ, Glynn MK, Groseclose SL. Completeness of notifiable infectious disease reporting in the United States: an analytical literature review. *Am J Epidemiol*. 2002 May 1;155(9):866-74.
32. Maffei R, Burciago D, Dunn K. Determining Business Models for Financial Sustainability in Regional Health Information Organizations (RHIOs): A Review. *Population Health Management*. October 2009, 12(5): 273-278
33. Johnston D, Pan E, Walker J. The value of CPOE in ambulatory settings. *J Healthc Inf Manag*. 2004 Winter;18(1):5-8.
34. Hripcsak G, Kaushal R, Johnson KB, Ash JS, Bates DW, Block R, Frisse ME, Kern LM, Marchibroda J, Overhage JM, Wilcox AB. The United Hospital Fund meeting on evaluating health information exchange. *J Biomed Inform*. 2007 Dec;40(6 Suppl):S3-10. Epub 2007 Aug 30.
35. Nobel JJ, Norman GK. Emerging information management technologies and the future of disease management. *Dis Manag*. 2003 Winter;6(4):219-31.
36. Stiell A, Forster AJ, Stiell IG, van Walraven C. Prevalence of information gaps in the emergency department and the effect on patient outcomes. *CMAJ*. 2003 Nov 11;169(10):1023-8.
37. Overhage JM, Dexter PR, Perkins SM, Cordell WH, McGoff J, McGrath R, McDonald CJ. A randomized, controlled trial of clinical information shared from another institution. *Ann Emerg Med*. 2002 Jan;39(1):14-23.
38. Eisenstein EL, Anstrom KJ, Macri JM, Crosslin DR, Johnson FS, Kawamoto K, Lobach DF. Assessing the potential economic value of health information technology interventions in a community-based health network. *AMIA Annu Symp Proc*. 2005:221-5.
39. Javitt JC, Steinberg G, Locke T, Couch JB, Jacques J, Juster I, Reisman L. Using a claims data-based sentinel system to improve compliance with clinical guidelines: results of a randomized prospective study. *Am J Manag Care*. 2005 Feb;11(2):93-102.
40. Adler-Milstein J, McAfee AP, Bates DW, Jha AK. The state of regional health information organizations: current activities and financing. *Health Aff (Millwood)*. 2008 Jan-Feb;27(1):w60-9. Epub 2007 Dec 11.
41. Levinson, D. State Medicaid Agencies' Initiatives On Health Information Technology and Health Information Exchange. Department of Health and Human Services. 2007.
42. Mathematica Policy Research. Health Information Exchange: The Role of Safety-Net Providers. June 2009.
43. Schiff GD, Bates DW. Can electronic clinical documentation help prevent diagnostic errors? *N Engl J Med*. 2010 Mar 25;362(12):1066-9.
44. Fox S, Szabo D, Burde H. Managing Information Privacy and Security in Healthcare. Guide to Establishing a Regional Health Information Organization. 2007
45. Sprivulis P, Walker J, Johnston D, Pan E, Adler-Milstein J, Middleton B, Bates DW. The economic benefits of health information exchange interoperability for Australia. *Aust Health Rev*. 2007 Nov;31(4):531-9.
46. AHIMA MPI Task Force. Building an Enterprise Master Person Index. *Journal of AHIMA* 75, no. 1 (Jan. 2004): 56A-D.
47. Daniel J, White J. Privacy and Security Solutions for Interoperable Health Information Exchange. RTI International. June 30, 2009
48. Appavu SI. Nationwide Interoperability. When standards are available at the application level, our health infrastructure will be a reality. *Healthc Inform*. 2005 Nov;22(11):22.
49. Frisse ME, King JK, Rice WB, Tang L, Porter JP, Coffman TA, Assink M, Yang K, Wesley M, Holmes RL, Gadd C, Johnson KB, Estrin VY. A regional health information exchange: architecture and implementation. *AMIA Annu Symp Proc*. 2008 Nov 6:212-6.
50. Miller RH, Sim I. Physicians' use of electronic medical records: barriers and solutions. *Health Aff (Millwood)*. 2004 Mar-Apr;23(2):116-26.
51. Osheroff JA, Teich JM, Middleton B, Steen EB, Wright A, Detmer DE. A roadmap for national action on clinical decision support. *J Am Med Inform Assoc*. 2007 Mar-Apr;14(2):141-5. Epub 2007 Jan 9.
52. Atalag K, Kingsford D, Paton C, Warren J. Putting Health Record Interoperability Standards to Work. *Electronic Journal of Health Informatics*. Vol 5(1): e1. 2010. <http://www.ejhi.net>
53. Hovenga E, Garde S. Electronic Health Records, Semantic Interoperability, and Politics. *Electronic Journal of Health Informatics*. Vol 5(1): e1. 2010. <http://www.ejhi.net>
54. Heard S. The Use of Standard Content Specifications in a National Health Interoperability Framework. *Electronic Journal of Health Informatics*. Vol 5(1): e1. 2010. <http://www.ejhi.net>
55. Heidenreich G, Angelidis PP. An Approach Towards Semantic Interoperability Using Domain Models. *Electronic Journal of Health Informatics*. Vol 5(1): e1. 2010.

<http://www.ejhi.net>

56. Hieb B. A Cost Effective Approach to Create a Universal Healthcare Identifier System. *Electronic Journal of Health Informatics*. Vol 5(1): e1. 2010. <http://www.ejhi.net>
57. Garde S, Hovenga E, Granz J, Foozonkhah S, Heard S. Managing Archetypes for Sustainable and Semantically Interoperable Electronic Health Records. *Electronic Journal of Health Informatics*. Vol 2(2). 2007. <http://www.ejhi.net>
58. Bloomrosen M, Detmer D. Advancing the Framework: Use of Health Data- A Report of a Working Conference of the American Medical Informatics Association. *Journal of American Medical Informatics Association*. Volume 15. Number 6. Nov/Dec 2008.
59. Center for Democracy and Technology. *Comprehensive Privacy and Security: Critical for Health Information Technology*. Version 1.0- May 2008. Accessed: October 3, 2010. <http://www.cdt.org/healthprivacy/20080514HPframe.pdf>
60. Congressional Budget Office. *Evidence on the Costs and Benefits of Health Information Technology*. The Congress of the United States. May 2008.
61. Dick R, Steen EB, Detmer D, Editors. Committee on Improving the Patient Record, Institute of Medicine. *The Computer Based Patient Record: An Essential Technology for Health Care*, Revised. Washington, DC: National Academy Press. 1997
62. Kaushal R, Jha AK, Franz C, Glaser J, Shetty KD, Jaggi T, et al. Return on investment for a computerized physician order entry system. *J Am Med Inform Assoc*.. 2006;13:261-6.
63. Frisse M. Comments on Return on Investment (ROI) As It Applies to Clinical Systems. *J Am Med Inform Assoc*. 2006 May-Jun; 13(3): 365-367.
64. Sittig DF, Krall M, Kaalaas-Sittig J, Ash JS. Emotional aspects of computer-based provider order entry: a qualitative study. *J Am Med Inform Assoc*.. 2005;12:561-7
65. Classen DC, Kanhouwa M, Will D, Casper J, Lewin J, Walker J. The patient safety institute demonstration project: a model for implementing a local health information infrastructure. *J Healthc Inf Manag*. 2005 Fall;19(4):75-86.
66. Kaushal R, Blumenthal D, Poon EG, Jha AK, Franz C, Middleton B, Glaser J, Kuperman G, Christino M, Fernandopulle R, Newhouse JP, Bates DW; Cost of National Health Information Network Working Group. The costs of a national health information network. *Ann Intern Med*. 2005 Aug 2;143(3):165-73.
67. McDonald CJ, Overhage JM, Barnes M, Schadow G, Blevins L, Dexter PR, Mamlin B; INPC Management Committee. The Indiana network for patient care: a working local health information infrastructure. An example of a working infrastructure collaboration that links data from five health systems and hundreds of millions of entries. *Health Aff (Millwood)*. 2005 Sep-Oct;24(5):1214-20.
68. Tang PC, Ash JS, Bates DW, Overhage JM, Sands DZ. Personal health records: definitions, benefits, and strategies for overcoming barriers to adoption. *J Am Med Inform Assoc*. 2006 Mar-Apr;13(2):121-6. Epub 2005 Dec 15.
69. Jha AK, Doolan D, Grandt D, Scott T, Bates DW. The use of health information technology in seven nations. *Int J Med Inform*. 2008 Dec;77(12):848-54. Epub 2008 Jul 25.
70. Kaushal R, Bates DW, Poon EG, Jha AK, Blumenthal D; Harvard Interfaculty Program for Health Systems Improvement NHIN Working Group. Functional gaps in attaining a national health information network. *Health Aff (Millwood)*. 2005 Sep-Oct;24(5):1281-9.
71. Baker LC. Benefits of interoperability: a closer look at the estimates. *Health Aff (Millwood)*. 2005 Jan-Jun;Suppl Web Exclusives:W5-22-W5-25.
72. Clayton PD, Naus SP, Bowes WA 3rd, Madsen TS, Wilcox AB, Orsmond G, Rocha B, Thornton SN, Jones S, Jacobsen CA, Udall MR, Rhodes ML, Wallace BE, Cannon W, Gardner J, Huff SM, Leckman L. Physician use of electronic medical records: issues and successes with direct data entry and physician productivity. *AMIA Annu Symp Proc*. 2005:141-5.
73. Evans DC, Nichol WP, Perlin JB. Effect of the implementation of an enterprise-wide Electronic Health Record on productivity in the Veterans Health Administration. *Health Econ Policy Law*. 2006 Apr;1(Pt 2):163-9.
74. Grossman JM, Reed MC. Clinical information technology gaps persist among physicians. *Issue Brief Cent Stud Health Syst Change*. 2006 Nov;(106):1-4.
75. Haynes RB, Wilczynski NL; Computerized Clinical Decision Support System (CCDSS) Systematic Review Team. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: methods of a decision-maker-researcher partnership systematic review. *Implement Sci*. 2010 Feb 5;5:12.
76. Garg AX, Adhikari NK, McDonald H, Rosas-Arellano MP, Devereaux PJ, Beyene J, Sam J, Haynes RB. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. 2005 Mar 9;293(10):1223-38.
77. Jha AK, Kuperman GJ, Rittenberg E, Teich JM, Bates DW. Identifying hospital admissions due to adverse drug events using a computer-based monitor. *Pharmacoepidemiol Drug Saf*. 2001 Mar-Apr;10(2):113-9.
78. Taylor R, Bower A, Giroso F, Bigelow J, Fonkych K, and Hillestad R, "Promoting Health Information Technology: Is There a Case for More-Aggressive Government Action?" *Health Affairs*, Vol. 24, No. 5, September 14, 2005.
79. Bigelow JH, Fonkych K, Fung C, and Wang J. *Analysis of Healthcare Interventions That Change Patient Trajectories*. RAND Corporation. MG-408-HLTH, 2005.
80. Fonkych K and Taylor R, *The State and Pattern of Health Information Technology Adoption*. RAND Corporation. MG-409-HLTH, 2005.
81. Giroso F, Meili R, and Scoville R, *Extrapolating Evidence of Health Information Technology Savings and Costs*. RAND Corporation. MG-410-HLTH, 2005.
82. Yasnoff WA, Humphreys BL, Overhage JM, Detmer DE, Brennan PF, Morris RW, Middleton B, Bates DW, Fanning JP. A consensus action agenda for achieving the national health information infrastructure. *J Am Med Inform Assoc*. 2004 Jul-Aug;11(4):332-8. Epub 2004 Jun 7.
83. Yasnoff WA, O'Carroll PW, Koo D, Linkins RW, Kilbourne EM. Public health informatics: improving and transforming public health in the information age. *J Public Health Manag Pract*. 2000 Nov;6(6):67-75.
84. Tierney WM, McDonald CJ, Martin DK, Rogers MP. Computerized display of past test results. Effect on outpatient testing. *Ann Intern Med*. 1987 Oct;107(4):569-74.
85. de Keizer N, Ammenwerth E. Trends in evaluation research 1982 - 2002: a study on how the quality of IT evaluation studies develop. *Stud Health Technol Inform* 2005;116:581-6.
86. Fehrenbach N, Ross D, Hastings T, Renahan-White A. Towards measuring value: an evaluation framework for public health information systems. Association of Public Health Laboratories, Public Health Informatics Institute Research Brief 2005 April.
87. Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. *J Biomed Inform* 2004 Feb;37(1):56-76.

88. Roderer, NK. Outcome measures in clinical information systems evaluation. *Stud Health Technol Inform* 2004;107(Pt2):1096-100.
89. Brailer DJ. Interoperability: the key to the future health care system. *Health Aff (Millwood)*. 2005 Jan-Jun;Suppl Web Exclusives:W5-19-W5-21.
90. Brailer DJ. David Brailer on a private-public health information technology infrastructure. Interview by Susan V. White. *J Healthc Qual*. 2004 Nov-Dec;26(6):20-4.
91. Friedlin FJ, McDonald CJ. A software tool for removing patient identifying information from clinical documents. *J Am Med Inform Assoc*. 2008 Sep-Oct;15(5):601-10. Epub 2008 Jun 25.
92. Kho AN, Lemmon L, Commiskey M, Wilson SJ, McDonald CJ. Use of a regional health information exchange to detect crossover of patients with MRSA between urban hospitals. *J Am Med Inform Assoc*. 2008 Mar-Apr;15(2):212-6. Epub 2007 Dec 20.
93. Drake TA, Braun J, Marchevisky A, Kohane IS, Fletcher C, Chueh H, Beckwith B, Berkowicz D, Kuo F, Zeng QT, Balis U, Holzbach A, McMurry A, Gee CE, McDonald CJ, Schadow G, Davis M, Hattab EM, Blevins L, Hook J, Becich M, Crowley RS, Taube SE, Berman J; Shared Pathology Informatics Network. A system for sharing routine surgical pathology specimens across institutions: the Shared Pathology Informatics Network. *Hum Pathol*. 2007 Aug;38(8):1212-25. Epub 2007 May 8.
94. Schadow G, Dhaval R, McDonald CJ, Ragg S. Integrative specimen information service - a campus-wide resource for tissue banking, experimental data annotation, and analysis services. *AMIA Annu Symp Proc*. 2006:1087.
95. McDonald CJ, Overhage JM, Barnes M, Schadow G, Blevins L, Dexter PR, Mamlin B; INPC Management Committee. The Indiana network for patient care: a working local health information infrastructure. An example of a working infrastructure collaboration that links data from five health systems and hundreds of millions of entries. *Health Aff (Millwood)*. 2005 Sep-Oct;24(5):1214-20.
96. Finnell JT, Overhage JM, Dexter PR, Perkins SM, Lane KA, McDonald CJ. Community clinical data exchange for emergency medicine patients. *AMIA Annu Symp Proc*. 2003:235-8.
97. Weiner M, Stump TE, Callahan CM, Lewis JN, McDonald CJ. A practical method of linking data from Medicare claims and a comprehensive electronic medical records system. *Int J Med Inform*. 2003 Aug;71(1):57-69.
98. McDonald CJ, Schadow G, Barnes M, Dexter P, Overhage JM, Mamlin B, McCoy JM. Open Source software in medical informatics--why, how and what. *Int J Med Inform*. 2003 Mar;69(2-3):175-84.
99. D Adler-Milstein, DW Bates, and AK Jha, U.S. Regional Health Information Organizations: Progress and Challenges. *Health Affairs*, 2009, 28(2): 483-492
100. Alfreds S, Masters E, Himmelstein J. Opportunities for Facilitating Electronic HIE in Publicly Funded Programs: Findings from Key Informant Interviews with Medicaid, SCHIP, Public Health, and State Employee Health Benefit Plan Leadership and Staff. 2008.
101. NORC at the University of Chicago. Health Information Exchange Economic Sustainability Panel: Final Report. U.S. Department of Health and Human Services Office of the National Coordinator for Health Information Technology. April 2009.
102. van den Brink, J., Moorman P, de Boer M, Pruyn J, Verwoerd C, vanBemmel J. Involving the patient: A prospective study on use, appreciation and effectiveness of an information system in head and neck cancer care. *International Journal of Medical Informatics*. 2005; 74:839-849.
103. Cusack CM, Pan E, Hook JM, Vincent A, Kaelber DC, Middleton B. The value proposition in the widespread use of telehealth. *J Telemed Telecare*. 2008; 167-168.
104. American Recovery and Reinvestment Act of 2009. Available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=11_cong_bills&docidf:h1enr.pdf. Accessed 28 August 2010.
105. Afilalo M, Lang E, Léger R, Xue X, Colacone A, Soucy N, Vandal A, Boivin JF, Unger B. Impact of a standardized communication system on continuity of care between family physicians and the emergency department. *CJEM*. 2007 Mar;9(2):79-86.
106. Lang E, Afilalo M, Vandal AC, Boivin JF, Xue X, Colacone A, Léger R, Shrier I, Rosenthal S. Impact of an electronic link between the emergency department and family physicians: a randomized controlled trial. *CMAJ*. 2006 Jan 31;174(3):313-8. Epub 2006 Jan 6.
107. Grossman JM, Bodenheimer TS, McKenzie K. Hospital-physician portals: the role of competition in driving clinical data exchange. *Health Aff (Millwood)*. 2006 Nov-Dec;25(6):1629-36.
108. Burton LC, Anderson GF, Kues IW. Using electronic health records to help coordinate care. *Milbank Q*. 2004;82(3):457-81, table of contents.
109. McGowan JJ, Jordan C, Sims T, Overhage JM. Rural RHIOs: common issues in the development of two state-wide health information networks. *AMIA Annu Symp Proc*. 2007 Oct 11:528-32.
110. Solomon MR. Regional health information organizations: a vehicle for transforming health care delivery? *J Med Syst*. 2007 Feb;31(1):35-47.
111. Middleton B, Fleming M, Wiegand T, et al. Best practices for community health information exchange. Available at www.dr-connect.com/downloads/CCHLBestPracticesGuide.pdf. Accessed 25 September 2010.
112. Frohlich J, Karp S, Smith MD, Sujansky W. Retrospective: lessons learned from the Santa Barbara project and their implications for health information exchange. *Health Aff (Millwood)*. 2007 Sep-Oct;26(5):w589-91. Epub 2007 Aug 1.
113. Ash JS, Guappone KP. Qualitative evaluation of health information exchange efforts. *J Biomed Inform* 2007;40(6 Suppl):S33-9.
114. Simon SR, Kaushal R, Jenter CA, et al. Readiness for electronic health records: comparison of characteristics of practices in a collaborative with the remainder of Massachusetts. *Inform Prim Care* 2008;16: 129-37.
115. Grossman JM, Kushner KL, November EA. Creating sustainable local health information exchanges: can barriers to stakeholder participation be overcome? *Ref Briefs* 2008;(2):1-12.
116. Marchibroda JM. Health information exchange policy and evaluation. *J Biomed Inform* 2007;40(6 Suppl): S11-6.
117. Rosenfeld S, Koss S, Caruth K, Fuller G. Evolution of state health information exchange: a study of vision, strategy, and progress. 2006. Available at http://www.avalerehealth.net/research/docs/State_based_Health_Information_Exchange_Final_Report.pdf. Accessed 24 July 2010.
118. Kern LM, Kaushal R. Health information technology and health information exchange in New York State: new initiatives in implementation and evaluation. *J Biomed Inform* 2007;40(6 Suppl):S17-20.
119. Doebbeling BN, Chou AF, Tierney WM. Priorities and strategies for the implementation of integrated informatics and communications technology to improve evidence-based

- practice. *J Gen Intern Med* 2006;21 Suppl 2):S50–7.
120. RHIO networks could spur growth of EMRs. *Mater Manag Health Care* 2006;15:5.
121. Terry K. The rocky road to RHIOs. *Med Econ* 2006;83:TCP8, TCP10-2.
122. Holmquest DL. Another lesson from Santa Barbara. *Health Aff (Millwood)* 2007;26:w592–4.
123. Ghosh T, Marquard J. Development of regional health information organizations (RHIOs): knowledge networks and collaboration. *Int J Public Pol* 2007;2:298–315.
124. Kaelber DC, Bates DW. Health information exchange and patient safety. *J Biomed Inform* 2007; 40(6 Suppl):S40–5.
125. Kilbridge PM, Classen DC. The informatics opportunities at the intersection of patient safety and clinical informatics. *J Am Med Inform Assoc* 2008;15: 397–407.
126. Noblin AM. Privacy policy analysis for health information networks and regional health information organizations. *Health Care Manag (Frederick)* 2007; 26:331–40.
127. Halamka J, Overhage JM, Ricciardi L, Rishel W, Shirky C, Diamond C. Exchanging health information: local distribution, national coordination. *Health Aff (Millwood)* 2005;24:1170–9.
128. Kuhn KA, Giuse DA, Lapa˜o L, Wurst SH. Expanding the scope of health information systems - from hospitals to regional networks, to national infrastructures, and beyond. *Methods Inf Med* 2007;46:500–2.
129. Carter P, Lemery C, Mikels D, Bowen R, Hjort B. Privacy and security in health information exchange. *J AHIMA* 2006;77:64A–64C.
130. Deloitte Center for Health Solutions. HIE business models: the path to sustainable financial success. 2006. Available at http://www.providersedge.com/ehdocs/ehr_articles/Health_Info_Exchange_Business_Model_s.pdf. Accessed 24 October 2010.
131. Diamond C, Ricciardi L. Building consumer trust into health information exchange. *J AHIMA* 2006; 77:36, 38.
132. Johnson KB, Gadd C. Playing smallball: approaches to evaluating pilot health information exchange systems. *J Biomed Inform* 2007;40(6 Suppl):S21–6.
133. Lawrence D. Doing it right. While the key to the perfect RHIO may still be a mystery, a number of them are off and running. *Healthc Inform* 2007;24: 38, 40.
134. Martin Z. Building a RHIO, bit by bit. *Health Data Manag.* 2007 Jun;15(6):58, 60.
135. Zafar A, Dixon BE. Pulling back the covers: technical lessons of a real-world health information exchange. *Medinfo* 2007;12(Pt 1):488–92.

Author Information

Jay K. Joshi

University of Chicago