Journal of the American Medical Informatics Association, 25(9), 2018, 1259–1265
doi: 10.1093/jamia/ocy035
Advance Access Publication Date: 28 April 2018
Review

Review

The benefits of health information exchange: an updated systematic review

Nir Menachemi,[1,2] Saurabh Rahurkar,[2] Christopher A Harle,[1,2] and Joshua R Vest[1,2]

[1]Department of Health Policy and Management, Indiana University (IU) Richard M. Fairbanks School of Public Health, Indianapolis, IN, USA and [2]Center for Biomedical Informatics, Regenstrief Institute, Indianapolis, IN, USA

Corresponding Author: Nir Menachemi, Department of Health Policy and Management, Indiana University (IU) Richard M. Fairbanks School of Public Health, Health Sciences Building, RG 5132, 1050 Wishard Blvd., Indianapolis, Indiana 46202, USA; nirmena@iu.edu

Received 8 January 2018; Revised 8 March 2018; Editorial Decision 16 March 2018; Accepted 18 March 2018

ABSTRACT

Objective: Widespread health information exchange (HIE) is a national objective motivated by the promise of improved care and a reduction in costs. Previous reviews have found little rigorous evidence that HIE positively affects these anticipated benefits. However, early studies of HIE were methodologically limited. The purpose of the current study is to review the recent literature on the impact of HIE.

Methods: We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to conduct our systematic review. PubMed and Scopus databases were used to identify empirical articles that evaluated HIE in the context of a health care outcome.

Results: Our search strategy identified 24 articles that included 63 individual analyses. The majority of the studies were from the United States representing 9 states; and about 40% of the included analyses occurred in a handful of HIEs from the state of New York. Seven of the 24 studies used designs suitable for causal inference and all reported some beneficial effect from HIE; none reported adverse effects.

Conclusions: The current systematic review found that studies with more rigorous designs all reported benefits from HIE. Such benefits include fewer duplicated procedures, reduced imaging, lower costs, and improved patient safety. We also found that studies evaluating community HIEs were more likely to find benefits than studies that evaluated enterprise HIEs or vendor-mediated exchanges. Overall, these finding bode well for the HIEs ability to deliver on anticipated improvements in care delivery and reduction in costs.

Key words: health information exchange, health information technology, health care costs, quality of health care, electronic health records, medical informatics

INTRODUCTION

Health information exchange (HIE), involves the electronic transfer of health information between health care organizations according to nationally recognized standards.[1] Recent initiatives such as the hospital readmission reduction program[2] as well as payment models including accountable care,[3] bundled payments,[4] and patient centered medical homes[5] have focused on coordination of care and data sharing for improved care quality. These models rely on HIE for success and subsequently for effective population health management by provider organizations.[6]

Despite the theoretical benefits, previous reviews of the HIE literature concluded that only weak evidence exists that links HIE to reduced costs, use of health services, or quality of care.[7–9] The reviews also found that many of the early studies were limited in terms of settings studied,[7,8] outcomes examined,[7–9] and a focus on both first-generation systems and the infrequent use of study designs suited for making causal attributions.[7–9] Nevertheless, the Medicare

Access and Children's Health Insurance Program Reauthorization Act of 2015 and other federal policies have encouraged the continued adoption of HIE by providers.[10] The ensuing widespread adoption of HIE[11] has brought new innovations to the HIE landscape including the proliferation of new HIE organizations that differ from the community HIEs that first existed. For example, enterprise HIE systems and vendor-mediated HIEs are more commonplace today.[12]

The purpose of the current study is to update a previous systematic review on the impact of HIE. First, we are interested in examining new evidence regarding how HIE may affect health care measures such as costs, use of services, and quality. Second, given the proliferation of new types of HIE organizations, we are interested in whether studies focused on community HIEs differ in their likelihood of reporting benefits when compared to studies focused on vendor-mediated or enterprise HIE systems. Lastly, we seek to determine the extent to which newly published studies have improved on the methodological shortcomings of earlier studies, by utilizing stronger research designs, focusing on a broader set of outcome measures, and/or examining more diverse populations and/or settings. The findings of our analysis will be beneficial to stakeholders interested in how HIE affects care; and to what degree the promised benefits of HIE are being realized.[13]

METHODS

Search Strategy

We replicated the search strategy used by Rahurkar et al.[7] which used a methodology consistent with the Preferred Reporting Items of Systematic Reviews and Meta Analyses guidelines.[14] Specifically, we searched the PubMed and Scopus databases from May 2014 to June 2017 (the period subsequent to the previous study) for any articles that evaluated the relationship between HIE and any resultant healthcare outcome measures. Similar to the previous study, we identified articles by searching for HIE-related and healthcare outcome related search terms together (See Supplementary materials, Appendix S1). We included only empirical peer-reviewed articles and thus excluded policy briefs, letters to the editor, governmental reports, commentaries, and other nonpeer-reviewed manuscripts.

The keyword search identified 1103 articles which we reviewed through the process shown in Supplementary Appendix S2. Two reviewers first screened titles and abstracts of these articles to identify articles that evaluated HIE in the context of healthcare. Next, we reviewed the screened articles to select those that evaluated the relationship between HIE and specific healthcare outcomes (i.e., healthcare utilization, healthcare costs, quality of care). Finally, we used a snowballing technique whereby we searched the reference lists of included articles to identify potentially missed studies that should be considered. We repeated this process on each additional article until no additional articles worthy of inclusion could be identified. At each stage, we resolved conflicts in inclusion or exclusion by discussion and achieving consensus among the reviewers.

Research Dataset

We identified 24 articles for inclusion that were published between May 2014 and June 2017. These 24 articles included 63 discreet analyses, which were of interest given that a study may have evaluated more than one outcome measure. We identified a discreet analysis based on a distinct dependent variable that was examined in a given study (e.g., repeat imaging tests, repeat diagnostic tests, and healthcare costs). For example, Park and coauthors evaluated HIE's impact on nine distinct analyses—total care costs, total drug costs, costs of four different types of tests, number of orders, number of outpatient visits, and length of hospital stay. For every article that was included, we extracted various information including type of study design used (cohort study, cross-sectional study, randomized controlled trial, quasi-experimental study), setting and population studied (primary care physicians, hospital, emergency department), and country of origin. Further, the dependent variables in each study were grouped into the following categories: health care services use (e.g., hospital or emergency department readmissions, redundant lab tests), health care costs (e.g., total care costs), disease surveillance (e.g., automatic reporting of diseases requiring public health notification), and quality-of-care measures (e.g., medication reconciliation, medication adherence).

Building on the gaps in literature that were identified in the prior systematic review, we extracted information, when possible, on whether or not a study measured actual usage of HIE in clinical care (Yes/No), the mechanism by which HIE information is accessed (Push/Pull), and the process by which patients consent to include their data in the HIE (Opt-in/Opt-out). We determined actual usage if a study observed HIE usage in each patient encounter or on the basis of HIE usage logs. We judged the mechanism of HIE as "Pull" if the clinician had to actively request or pull a patient's information from the HIE. We judged the mechanism of HIE as "Push" if patient information from HIE was automatically provided without the clinician taking action. We determined the patient consent model to be "Opt-out" if all patients were enrolled for participation in HIE unless a given patient explicitly objected and was thus excluded. For each analysis in each included study, we also extracted information on the nature of the relationship between HIE and the dependent variable studied. We identified a relationship as beneficial if there was a statistically significant positive association for positive outcomes or a negative association for negative outcomes. The evidence in support of the identified relationship was considered "high-quality" if the study used a design that had strong internal validity, which included randomized controlled trials or quasi-experimental approaches.

Finally, we combined the information on the newly identified studies in the current systematic review with the studies identified in the previous systematic review by Rahurkar et al. This resulted in a sample of 51 studies (27 from previous review + 24 in the current review) consisting of 157 analyses (94 from previous review + 63 newly identified). For all studies in the final sample, we extracted information on the type of HIE investigated (community HIE, enterprise HIE, or vendor-mediated HIE). This enabled us to examine whether HIE type was related to the likelihood of finding a beneficial relationship across all 51 studies. Unfortunately, data regarding push/pull and opt in/out was not available from studies covered in the previous systematic review.

Analytical Approach

We descriptively analyzed each of the extracted variables to examine the nature of the published articles included in the current study. Next, we used Chi-square analysis or Fisher's exact test, as appropriate, to investigate how each study characteristic was associated with reporting a beneficial impact from HIE. For example, with respect to setting, we examined whether studies conducted in emergency departments were more or less likely to report beneficial effects from HIE compared to studies in primary care or other settings. Given the nature of how analyses are nested within articles in

our dataset, we specified a regression model that examined the relationship between finding a beneficial effect and the aforementioned study characteristics while adjusting for clustering at the article level. The results of this model appear in the Supplementary Appendix S3 and did not change the general conclusions we report below. Importantly, several cell sizes in the model were small given the sample size we have. Thus, we present the bivariate relationships in the results section. We conducted all analyses in STATA/MP version 15, and statistical significance was considered to be $P < .05$.

RESULTS

The 24 articles that include 63 analyses identified by our search strategy are described in Table 1. Also presented are the bivariate relationships between each extracted article characteristic and whether the analysis concluded a beneficial relationship with HIE. Among all analyses, 68.3% reported a beneficial effect from HIE; and 7.9% reported an unexpected adverse effect. The remaining analyses reported no effect.

Overall, the majority of studies were from the United States and country of study location was not statistically associated with likelihood of finding benefits from HIE. We present the name of the HIE organizations represented in the included articles and their corresponding state in Table 2. Overall, only 9 states were represented with any included study; and 25 out of 63 included analyses (39.7%) occurred in a handful of HIEs from the state of New York.

Whereas the majority of analyses used cohort designs, there were 13 analyses, contained within 7 studies, which used more rigorous randomized-controlled trials or quasi-experiments. There were no differences by study design in the likelihood of reporting a beneficial effect from HIE. Similarly, Pull vs Push HIE mechanisms was unrelated to finding HIE benefits. Lastly, the most common analyses focused on a measure of health care utilization ($n = 25$, 39.7%); and these analyses were less likely than others to conclude a beneficial effect from HIE (48% for utilization vs 77.8% for health care costs, 90% for quality of care, 80% for disease surveillance/public health; $P = .05$).

Healthcare Utilization

The evidence base for this outcome consisted of 25 analyses, of which 12 (48%) found a beneficial effect from HIE. HIE was associated with improved performance on hospital and 30-day readmissions,[15–18] ICU and ED admissions,[19,20] repeated imaging,[18,20–23] therapeutic medical procedures,[24] and total number of orders.[25] One cohort study, based in Israel, reported that HIE was adversely related to the number of imaging tests ordered.[26]

Healthcare Costs

The evidence base for this outcome consisted of 18 analyses, of which 14 (77.8%) found a beneficial effect from HIE. Specifically, HIE was associated with a reduction of total costs of care,[16,17,20,25,27–29] lab test costs,[25,30] imaging test costs,[18,25,27,30] and overall measures of return on investment.[28,29] One cohort study, conducted in the Veteran Health Administration, found that HIE was adversely associated with total unadjusted health care costs 1 year post HIE enrollment.[31]

Healthcare Quality

The evidence base for this outcome consisted of 10 analyses, of which 9 (90%) found a beneficial effect from HIE. For example, HIE was associated with improved medication reconciliation,[32] immunization and health record completeness,[33,34] a reduction in care disparities,[35] and HIV-related quality of care measures.[35]

Table 1. Bivariate Relationships Between Various Study Characteristics and Finding a Beneficial Effect from HIE on the Outcome Studied ($n = 24$ articles that include $n = 63$ analyses)

Variable	Study finding reported as beneficial (%)	*P*-value
Study location		
United States ($n = 48$)	73.0	.16
Other ($n = 15$)	53.3	
Study design		
Cohort ($n = 46$)	63.0	.19
Cross-sectional ($n = 4$)	100	
Quasi-experimental ($n = 9$)	88.9	
Randomized controlled trial ($n = 4$)	50.0	
Outcome		
Health care utilization (e.g., 30-day readmissions, repeat imaging, etc.) ($n = 25$)	48.0	.04
Health care costs (e.g., Diagnostic imaging costs, health care costs, etc.) ($n = 18$)	77.8	
Quality of care (e.g., Adverse drug events, medication reconciliation, etc.) ($n = 10$)	90.0	
Disease surveillance/Public Health (e.g., Immunization rates, reportable conditions reporting, etc.) ($n = 10$)	80.0	
Setting		
Inpatient ($n = 19$)	57.9	.46
Emergency Department ($n = 17$)	58.8	
Outpatient ($n = 13$)	76.9	
Community ($n = 7$)	85.7	
HIV Care ($n = 3$)	100	
Inpatient and outpatient ($n = 2$)	50.0	
Long term care ($n = 2$)	100	
HIE type		
Community HIE ($n = 31$)	74.2	.25
Enterprise HIE ($n = 19$)	68.4	
Vendor-mediated HIE ($n = 11$)	45.5	
Unspecified HIE ($n = 2$)	100	
HIE mechanism		
Pull ($n = 31$)	67.7	.91
Push ($n = 24$)	66.7	
Unknown or unspecified ($n = 8$)	75.0	

Disease Surveillance and Public Health

The evidence base for this outcome consisted of 10 analyses, of which 8 (80%) found a beneficial effect from HIE. Specifically, HIE was linked with improved population level immunization rates,[33] the timeliness of reporting of reportable conditions,[34] identification of drug seeking behaviors,[21] and improved surveillance of high ED utilizing vulnerable patients.[36]

Rigorous Studies

Seven of the 24 studies (including 13 of 63 analyses) utilized designs more suitable for generating high-quality evidence. We present a

Table 2. Name of the HIE Organizations Represented in the Literature (2014–2017) ($n = 24$ articles)

HIE (no. of studies)	State	Outcomes analyzed, *n* (%)
New York-Presbyterian Ambulatory Care Network ($n = 1$)	NY	9 (14.3)
Rochester RHIO ($n = 3$)	NY	6 (9.5)
Bronx RHIO ($n = 2$)	NY	4 (6.4)
HEALTHeLINK ($n = 2$)	NY	4 (6.4)
Healthix ($n = 1$)	NY	1 (1.6)
Epic ($n = 2$)	MI, MN, WI	8 (12.7)
Indiana health information exchange ($n = 1$)	IN	3 (4.8)
Veterans affairs/virtual lifetime electronic record ($n = 1$)	IN	1 (1.6)
Laboratory HIE ($n = 1$)	CA	3 (4.8)
Cerner ($n = 1$)	OK	2 (3.2)
Unknown or unspecified HIE ($n = 5$)	WA, SC	7 (11.1)
Non-US HIE ($n = 4$)		15 (23.8)
Total		63 (100)

synthesis of these 7 studies in Table 3. All 7 studies reported at least some beneficial effect from HIE (including 10 of 13 analyses); none reported adverse effects. Two of these studies focused on the emergency settings,[30,37] 2 studies examined outpatient settings,[17,24] and 1 study each examine the inpatient,[32] community,[27] and HIV care setting,[35] respectively. Outcomes that improved with HIE included hospital admissions,[17] total costs of care,[17,24,27,30,37] improved medication reconciliation,[35] and HIV-related quality of care measures.[35]

HIE Type

In order to examine the relationship between HIE type and the likelihood of reporting benefits from HIE, we utilized the combined data set including the 51 individual articles described above. Twenty-seven of the 51 studies (52.9%) assessed community HIEs. Studies assessing a community HIE were more likely to report a benefit effect compared to studies that examined other types of HIEs (70.3% vs 54.2%, $P = .04$).

DISCUSSION

Previous reviews of the HIE literature found that evidence for HIE came most frequently from studies with weak internal validity. Moreover, studies with greater internal validity were less likely to report benefits from HIE.[7] In contrast, our current review of the literature finds that a greater number of recent studies utilized study designs more suitable for determining causality; and invariably these studies reported benefits from HIE. This change may be due to several factors including the likelihood that HIE, like other information technologies, is subjected to a learning curve in implementation, usage, and system effectiveness. More recent studies may have evaluated more mature HIEs that have evolved to be more effective than earlier-generation systems previously studied. If so, this finding bodes well for HIEs ability to deliver on anticipated improvements in the delivery of care.

Our study also improves upon the previous reviews by examining the association of HIE type and its relationship with outcomes. Importantly, we found that studies that evaluated community HIEs were significantly more likely to find benefits than studies that focused on other types of HIEs. By design, the community HIE model may be better positioned to actually realize the impacts of information exchange on cost, quality, and utilization outcomes. Patients seek care from multiple organizations, and fragmentation of patient information and poor information sharing during transitions of care are underlying drivers of duplicate costs, readmissions, poor medication reconciliation, and repeat imaging. Community HIEs attempt to facilitate information exchange among the widest set of available providers within an area. As a result, community HIEs are positioned to provide access to the broadest range of patient information. In contrast, enterprise HIE or vendor-mediated HIEs have narrower exchange networks and, therefore, may not have access to the range of patient information necessary to address the challenges that result in poor outcomes.[38] At the same time, it is possible that the observed differences in benefits by HIE type is confounded by technology maturation, given that enterprise and vendor-mediated HIEs tend to be newer than community HIEs.

Compared to previous reviews, we currently found that, while the evidence base for HIE has improved in terms of the rigor of study designs, and types of HIEs studied, less gains were observed in the type of settings evaluated and especially the outcome measures studied. In terms of settings, HIE research continues to be dominated by the emergency department setting. The emergency care use case was among the earliest justifications for pursuing HIE, because a technology that allows providers to access information from other organizations on unfamiliar patients in a timely manner fits well with emergency care information needs.[39] Additionally, hospitals have been quicker to adopt interoperable health information technology than ambulatory care providers, so the opportunities for evaluation have been greater.[40] While the emergency department will continue to be an important use case for HIE, as reimbursement policies and organizational strategies attempt to move patients away from emergency department care, the impact of HIE in primary and specialty ambulatory care needs to be further examined. With respect to settings, we note that several studies examined the community level[22,27,34] or a long-term care setting,[15] neither of which were represented in a previous systematic review.[7] In terms of outcomes studied, utilization and cost-related outcomes remain the most frequently studied consequences of HIE. However, better access to patient information may also benefit patient health outcomes, such as through improved case management, care coordination, and clinical decision-making. Likewise, HIE may benefit organizational performance, such as through improved physician productivity. Thus, there is an opportunity for future studies that examine several other healthcare process and outcome measures.

Consistent with previous reviews of the literature, our study highlights a potential limitation pertaining to the generalizability of the current HIE literature. Specifically, a large number of existing studies emanate from a small number of organizations in a limited number of states. We found that HIEs operating in the state of New York are currently the most frequently studied. The preponderance of articles stemming from New York is likely due to the state's substantial public and private investments aimed at fostering interoperable health information technology adoption along with the commitment to evaluate this state-level policy intervention.[41] In addition to state funding, several community's served by HIEs in New York have qualities that favor HIE impact studies, including very large numbers of events, highly fragmented patient care patterns between emergency departments, and histories of innovative health care quality improvement. Recently, New York State made HIE participation a requirement for hospitals and urgent care providers.[42]

Table 3. Overview of Experimental and Quasi-experimental Studies and Their Findings

Study reference	Study design	Population type	Effect on outcome	Findings
Eftekhari et al.[24] (2017)	Quasi-experimental: Instrumental Variable	Outpatient	Beneficial effect	HIE tenure was related to a significant reduction in the repetition of therapeutic medical procedures HIE tenure had no effect on the reduction of repetition of diagnostic medical procedures
Boockvar et al.[32] (2017)	Randomized controlled trial as well as difference-in-difference	Inpatient	Beneficial effect	A significantly greater number of medication discrepancies were identified when HIE was used No effect was seen in the number of adverse drug events experienced when HIE was used
Murphy et al.[37] (2017)	Randomized controlled trial	Emergency Department	Beneficial effect	Over a 12-month period costs HIE use resulted in $3200 savings related to ED use
Cunningham et al.[35] (2017)	Quasi-experimental: Interrupted time series	HIV care	Beneficial effect	Use of Laboratory HIE was associated with higher odds of anti-retroviral therapy, viral suppression, and reduced racial disparities
Yaraghi[30] (2015)	Quasi-experimental	Emergency Department	Beneficial effect	HIE usage was associated with a significant reduction in both laboratory tests as well as radiology examinations ordered per patient
Jung et al.[27] (2015)	Quasi-experimental: Propensity score matching	Community	Beneficial effect	HIE usage was related to reduction in repeat imaging. Reduced repeat imaging was significantly related to annual savings of $32 460
Vest et al.[17] (2015)	Quasi-experimental: Propensity score matching	Outpatient	Beneficial effect	HIE usage was related to reduction lower odds of readmission. This reduction was related to estimated savings of $605 000

Therefore, it is unclear if HIE efforts in states with less concerted efforts to support health information technology and quality improvement, will experience similar benefits. Critically, however, the ultimate objective is not to foster exchange within one community or one state, but to have information nationally accessible. We note that empirical evidence on the impact of HIE across state lines is scant.

Given the findings of our review, there is a need for continued policies to encourage widespread HIE activity. Encouragingly, at the federal level, Congress has declared "it a national objective to achieve widespread exchange of health information."[10] Likewise, the Office of the National Coordinator for Health Information Technology has clearly defined behaviors that create unnecessary and artificial barriers to HIE as information blocking.[43] Nevertheless, challenges remain. Provider claims of information blocking behavior are not uncommon.[43] And, while adoption of interoperable health information technology is growing, the use of HIE by hospitals and individual providers is far from universal.[44,45]

Limitations

Our study has the following limitations. First, our search strategy found only 24 articles that were included in our review which makes more complex statistical or meta-analyses difficult to perform. However, the narrative findings that we present are minimally sensitive to sample sizes. Also, it is possible that our search strategy missed some articles that should have been included. Along the same lines, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to structuring our review and recognize that other approaches exist which may have yielded different studies to be included.[46] Nevertheless, to minimize this risk, we used an iterative snowball technique to identify articles from bibliographic lists of included articles until no new articles were found. Additionally, because most of the included studies came from a select few states; and were limited in the settings and outcomes studied, we recognize that the generalizability of our findings may be limited. Lastly, we did not employ an expert panel in the selection of our search terms, nor did we submit an a priori protocol to a publically available repository such as PROSPERO.[47]

CONCLUSION

Overall, our systematic review of the literature found that high quality evidence exists to link HIE with a reduction in healthcare utilization and costs. This represents progress in reaching the national goals of more accessible patient information in support of the triple aim of better quality, improved population health, and lower costs.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

COMPETING INTERESTS

None.

CONTRIBUTORS

This work represents the original research of the authors. This work has not been previously published. NM conceptualized the study. NM and SR drafted the manuscript and conducted the analyses. All authors participated in interpretation of the data. CH and JV provided critical revisions to the manuscript. All authors approved the submission.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

REFERENCES

1. National Alliance for Health Information Technology. *Report to the Office of the National Coordinator for Health Information Technology on Defining Key Health Information Technology Terms*. 2008.
2. Jackson CT, Trygstad TK, DeWalt DA, DuBard CA. Transitional care cut hospital readmissions for North Carolina Medicaid patients with complex chronic conditions. *Health Affairs (Project Hope)* 2013;32(8):1407–15.
3. DeVore S, Champion RW. Driving population health through accountable care organizations. *Health Aff* 2011;30(1):41–50.
4. Williams C, Mostashari F, Mertz K, Hogin E, Atwal P. From The Office Of The National Coordinator: the strategy for advancing the exchange of health information. *Health Aff* 2012;31(3):527–36.
5. Finkelstein J, Barr MS, Kothari PP, Nace DK, Quinn M. Patient-centered medical home cyberinfrastructure current and future landscape. *Am J Prev Med* 2011;40(5 Suppl 2):S225–33.
6. Vest JR, Harle CA, Schleyer T, *et al*. Getting from here to there: health IT needs for population health. *Am J Manag Care* 2016;22(12):827–29.
7. 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 Affairs (Project Hope)* 2015;34(3):477–83.
8. 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.
9. Hersh WR, Totten AM, Eden KB, *et al*. Outcomes from health information exchange: systematic review and future research needs. *JMIR MedI Inform* 2015;3(4):e39.
10. H.R.2 - Medicare Access and CHIP Reauthorization Act of 2015. *Public Law 114-10. 2015–2016 ed*. 2015. https://www.congress.gov/bill/114th-congress/house-bill/2/text. Accessed February 28, 2018.
11. Patel V, Hennry JW, Pylypchuk Y, Searcy T. Interoperability among U.S. *Non-federal Acute Care Hospitals in 2015*. Washington, DC: ONC Data Brief: Office of the National Coordinator for Health Information Technology; 2016.
12. Vest JR, Kash BA. Differing strategies to meet information-sharing needs: publicly supported community health information exchanges versus health systems' enterprise health information exchanges. *Milbank Q* 2016;94(1):77–108.
13. Blumenthal D. Launching HITECH. *New Engl J Med* 2010;362(5):382–5.
14. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6(7):e1000097.
15. Yeaman B, Ko KJ, Alvarez del Castillo R. Care transitions in long-term care and acute care: health information exchange and readmission rates. *Online J Issues Nurs* 2015;20(3):5.
16. Unruh MA, Jung HY, Kaushal R, Vest JR. Hospitalization event notifications and reductions in readmissions of Medicare fee-for-service beneficiaries in the Bronx, New York. *J Am Med Inform Assoc* 2017;24(e1):e150–56.
17. Vest JR, Kern LM, Silver MD, Kaushal R, investigators H. The potential for community-based health information exchange systems to reduce hospital readmissions. *J Am Med Inform Assoc* 2015;22(2):435–42.
18. Saef SH, Melvin CL, Carr CM. Impact of a health information exchange on resource use and Medicare-allowable reimbursements at 11 emergency departments in a midsized city. *Western J Emerg Med* 2014;15(7):777–85.
19. Politi L, Codish S, Sagy I, Fink L. Use patterns of health information exchange systems and admission decisions: reductionistic and configurational approaches. *Int J Med Inform* 2015;84(12):1029–38.
20. Everson J, Kocher KE, Adler-Milstein J. Health information exchange associated with improved emergency department care through faster accessing of patient information from outside organizations. *J Am Med Inform Assoc* 2017;24(e1):e103–10.
21. Winden TJ, Boland LL, Frey NG, Satterlee PA, Hokanson JS. Care everywhere, a point-to-point HIE tool: utilization and impact on patient care in the ED. *Appl Clin Inform* 2014;5(2):388–401.
22. Vest JR, Kaushal R, Silver MD, Hentel K, Kern LM. Health information exchange and the frequency of repeat medical imaging. *Am J Manag Care* 2014;20(11 Spec No. 17):eSP16–24.
23. Welk B, Liu K, Al-Jaishi A, McArthur E, Jain AK, Ordon M. Repeated diagnostic imaging studies in Ontario and the impact of health information exchange systems. *Healthc Q* 2016;19(1):24–8.
24. Eftekhari S, Yaraghi N, Singh R, Gopal RD, Ramesh R. Do health information exchanges deter repetition of medical services? *ACM Transact Manag Inform Syst* 2017;8(1):1–27.
25. Park H, Lee SI, Hwang H, *et al*. Can a health information exchange save healthcare costs? Evidence from a pilot program in South Korea. *Int J Med Inform* 2015;84(9):658–66.
26. Shabtai I, Ben-Assuli O, Leshno M. The connection between viewing medical historical information and using-clinical tests. *Int J Networking Virtual Organ* 2016;16(2):157.
27. Jung HY, Vest JR, Unruh MA, Kern LM, Kaushal R, Investigators H. Use of health information exchange and repeat imaging costs. *J Am College Radiol* 2015;12(12 Pt B):1364–70.
28. Murphy SM, Neven D. Cost-effective: emergency department care coordination with a regional hospital information system. *J Emerg Med* 2014;47(2):223–31.
29. Walker DM. Does participation in health information exchange improve hospital efficiency? *Health Care Manag Sci* 2017:1–13.
30. Yaraghi N. An empirical analysis of the financial benefits of health information exchange in emergency departments. *J Am Med Inform Assoc* 2015;22(6):1169–72.
31. French DD, Dixon BE, Perkins SM, *et al*. Short-term medical costs of a VHA health information exchange: a CHEERS-Compliant Article. *Medicine (Baltimore)* 2016;95(2):e2481.
32. Boockvar KS, Ho W, Pruskowski J, *et al*. Effect of health information exchange on recognition of medication discrepancies is interrupted when data charges are introduced: results of a cluster-randomized controlled trial. *J Am Med Inform Assoc* 2017;24(6):1095–101.
33. Stockwell MS, Natarajan K, Ramakrishnan R, *et al*. Immunization data exchange with electronic health records. *Pediatrics* 2016;137(6):e20154335.
34. Dixon BE, Zhang Z, Lai PTS, *et al*. Completeness and timeliness of notifiable disease reporting: a comparison of laboratory and provider reports submitted to a large county health department. *BMC Med Inform Decis Mak* 2017;17(1):87.
35. Cunningham WE, Ford CL, Kinsler JJ, *et al*. Effects of a laboratory health information exchange intervention on antiretroviral therapy use, viral suppression, and racial/ethnic disparities. *J Acquir Immune Defic Syndr* 2017;75(3):290–98.
36. Shy BD, Kim EY, Genes NG, *et al*. Increased identification of emergency department 72-hour returns using multihospital health information exchange. *Acad Emerg Med* 2016;23(5):645–9.

37. Murphy SM, Howell D, McPherson S, Grohs R, Roll J, Neven D. A randomized controlled trial of a citywide emergency department care-coordination program to reduce prescription opioid-related visits: an economic evaluation. *J Emerg Med* 2017;53(2):186–94.
38. Vest JR, Menachemi N. A population ecology perspective on the functioning and future of health information organizations. *Health Care Manag Rev* 2017 Nov 1. doi: 10.1097/HMR.0000000000000185 [Epub ahead of print].
39. Shapiro JS, Kannry J, Lipton M, *et al*. Approaches to patient health information exchange and their impact on emergency medicine. *Ann Emerg Med* 2006;48(4):426–32.
40. Adler-Milstein J, McAfee AP, Bates DW, Jha AK. The state of regional health information organizations: current activities and financing. *Health Affairs (Project Hope)* 2008;27(1):w60–9.
41. Kern LM, Barron Y, Abramson EL, Patel V, Kaushal R. HEAL NY: Promoting interoperable health information technology in New York State. *Health Affairs (Project Hope)* 2009;28(2):493–504.
42. New York State. *Statewide Health Information Network for New York (SHIN-NY)*. 2016. https://regs.health.ny.gov/sites/default/files/pdf/recently_adopted_regulations/2016-03-09_shin_ny.pdf. Accessed March 9, 2016.
43. The Office of the National Coordinator for Health Information Technology (ONC). *Report to Congress on Health Information Blocking*. Washington, DC: U.S. Department of Health and Human Services; 2015.
44. 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 Affairs (Project Hope)* 2014;33(9):1672–9.
45. Holmgren AJ, Patel V, Adler-Milstein J. Progress in interoperability: measuring US Hospitals' engagement in sharing patient data. *Health Affairs (Project Hope)* 2017;36(10):1820–27.
46. Fleming PS, Koletsi D, Pandis N. Blinded by PRISMA: are systematic reviewers focusing on PRISMA and ignoring other guidelines? *PLoS ONE* 2014;9(5):e96407.
47. National Institute of Health Research. *PROSPERO*. 2018. https://www.crd.york.ac.uk/prospero/#aboutpage. Accessed February 28, 2018.