Healthcare 7 (2019) 100358

Contents lists available at ScienceDirect

Healthcare

journal homepage: www.elsevier.com/locate/healthcare

Original research

Uncovering differences in interoperability across hospital size

Yuriy Pylypchuk[a,*], Carla S. Alvarado[b], Vaishali Patel[a], Talisha Searcy[a]

[a] Office of the National Coordinator for Health Information Technology, U.S. Department of Health and Human Services, 330 C St SW, Floor 7, Washington, DC, 20201, USA

[b] National Academies of Sciences, Engineering, and Medicine, Washington, DC, USA

A B S T R A C T

Background: Small hospitals significantly lag behind large hospitals in interoperable health information exchange. This analysis identifies factors that explain differences in interoperability between these hospital types. We place a particular emphasis on such factors as number of functionalities within electronic health record system (EHR), participation in regional and national networks, and adoption of a dominant EHR.

Methods: Using data from the 2017 American Hospital Association (AHA) Annual Survey Information Technology Supplement (n = 2789 hospitals), we applied a Blinder-Oaxaca decomposition technique to explain differences in each domain of interoperability. Interoperability is defined as a hospitals' ability to electronically send, receive, and integrate summary of care records into their EHR and electronically find patient health information from external sources.

Results: The percentage of small and large hospitals engaged in each interoperability domain increased between 2015 and 2017; however, the gap between these hospital types remained mostly the same. Differences in characteristics explained most of the gap in integrating, finding and receiving the data while differences in characteristics and returns to characteristics were significant in explaining the differences in sending the data. The number of EHR functionalities and participation in national and regional networks were among largest contributors to the gap.

Conclusions: The lack of participation in multiple networks and the number of functionalities in EHRs among small hospitals are key factors that explain the difference in interoperability between small and large hospitals. Policies that incentivize these activities or simplify electronic exchange could reduce gaps in interoperability among hospitals of different sizes.

1. Introduction

Health Information Technology for Economic and Clinical Health (HITECH) act (2009) allocated nearly $30 billion for development and adoption of technology capable to support interoperable heath information exchange. As part of these efforts, hospitals reached nearly hundred percent adoption of certified EHRs.[1] However, challenges remain in other area of health information technologies. In particular, large differences exist among hospitals of different sizes in interoperable health information exchange. In 2017, small hospitals were trailing large hospitals in their ability to electronically find health information and electronically send, receive, and integrate summary of care records by over 10 percentage points (Table 1). This trend has been consistent since 2015, yet factors that account for this gap remain largely unknown.

All critical access hospitals (CAHs) and 80% of rural hospitals are considered small (with less than 100 beds) and are in particular need for interoperable exchange of health information.[2,3] They often experience transfer of patients to other institutions either due to their limited bed size or scope of services,[4] yet they also experience back transfers because patients return to their local hospital for completion of medical treatment.[5] Interoperable exchange of health records in these cases could be critical for appropriate care. Literature found that small hospitals have lower performance on some processes of care and quality measures[6–8]; however, evidence suggests that electronic exchange of health information often improves patients care.[9–11] Finally, small hospitals often serve communities where residents are typically older and have higher rates of chronic conditions.[12] These circumstances underscore the importance for these facilities to have the same capacity for interoperable exchange as large and it serves as a motivation for our analysis.

Previous studies established that certain types of hospitals lag behind in adoption and use of health information technologies. Milstein et al. (2017) found that CAHs were less likely to adopt performance measures and patient engagement functions.[13] Sandefer et al. (2015) found that rural and CAHs were consistently less likely to attest to meaningful use during 2011–2013.[14] Both studies raise a concern about the emergence and widening of the digital divide between urban hospitals and their counterparts.

Prior studies focused on the investigation of factors that are associated with hospitals' interoperability. The findings indicate that hospitals' participation in regional or state health information exchange organizations (HIOs), the sophistication of their EHR system, system ownership, and the use of a dominant vendor are positively associated

* Corresponding author.
E-mail address: yuriy.pylypchuk@hhs.gov (Y. Pylypchuk).

https://doi.org/10.1016/j.hjdsi.2019.04.001
Received 30 October 2018; Received in revised form 26 March 2019; Accepted 1 April 2019
Available online 16 April 2019
2213-0764/ Published by Elsevier Inc.

Table 1
Percent hospitals of finding, integrating, sending and receiving summary of care records by hospital size.

	Find (SE)	Integrate (SE)	Send (SE)	Receive (SE)
2015 (n = 2787)				
Small	42.7 (0.01)	31.3 (0.01)	79.9 (0.01)	58.1 (0.01)
Large	65.8 (0.01)	44.9 (0.01)	90.3 (0.01)	70.6 (0.01)
Gap	23.1 (0.02)	13.6 (0.02)	10.4 (0.01)	12.2 (0.02)
2017 (n = 2789)				
Small	50.0 (0.01)	46.9 (0.01)	82.7 (0.01)	65.8 (0.02)
Large	72.0 (0.02)	59.4 (0.01)	93.4 (0.01)	81.9 (0.01)
Gap	22.0 (0.02)	12.5 (0.02)	10.8 (0.01)	16.2 (0.02)

Source: Authors' calculation using 2015 and 2017 AHA Annual Survey Health Information Technology Supplement.

with interoperability.[15–17] However, it remains unknown whether these factors account for the current differences in interoperability across hospitals of different sizes.

The objective of our analysis is to identify the extent to which observable characteristics explain differences in interoperability between small and large hospitals. We apply Oaxaca (1973)-Blinder (1973) estimation technique to decompose the interoperability gap into two components.[18,19] The first component identifies how much of the gap is explained by differences in observed characteristics; it estimates the share of the gap that can be explained if average characteristics are the same among small and large hospitals. The second component identifies percent of the gap explained by the differences in coefficients. This is a behavioral component, which measures differences in returns hospital derive from characteristics. We identify these components for each characteristic and for all observables in the model. We use framework and specifications developed in prior studies as a guide for selecting hospitals' characteristics in our application.[15–17]

The results of our analysis answer the following policy questions. What would happen to the differences in interoperability if small hospitals adopted the same EHRs as large hospitals? Do small hospitals derive the same returns from technologies as large hospitals do? And, how much of the difference in interoperability would change if small and large hospitals had the same characteristics?

2. Data

For the multivariate and decomposition analysis we use data from the 2017 American Hospital Association's (AHA) Annual Survey Information Technology Supplement (IT Supplement), which collects information on key interoperability and other Health IT adoption measures as well as hospital characteristics. The analytic sample consists of 2789 observations that only include non-federal acute care hospitals that responded to the IT Supplement (in 2017, 64% of hospitals responded to the IT Supplement).

We focus on non-federal acute care hospitals; however, similar inequalities may exist across other institutions such as long-term care and children's hospitals and clinics, among others. They also exhibit frequent transitions of patients and are in need of interoperable data exchange. Future studies that examine sources of differences across these institutions will enhance our understanding about an unequal interoperability engagement across health care settings.

Few additional data sources were used to supplement our analysis. We pooled a corresponding sample from 2015 AHA IT Supplement to illustrate the trends in interoperability domains across hospital types. Additionally, we used 2016 HIMSS and 2016 administrative data from CMS EHR Incentive Program to capture whether a hospital's EHR vendor is dominant within its referral region (HRR).

2.1. Outcome variables

We used measures of interoperability used by ONC which comprise the following four domains: 1) *sending* summary of care records, 2) *receiving* summary of care records, 3) electronically *finding* the data, and 4) *integrating* summary of care records. The *sending* and *receiving* measures were constructed based on whether a hospital "often or sometimes" used the following methods of patient information exchange: provider portal, interface connection between EHR systems, direct access to EHRs, standalone health information service provider (HISP), community (regional, state, or local) health information exchange organization (HIO), single or multi-EHR vendor network, multi-EHR vendor networks, and e-Health exchange, among other methods.

An EHR's ability to integrate health information without manual input is a key element of interoperability.[20] We capture hospital's engagement to integrate patient's summary of care records into EHR using the following question "Does your EHR integrate the information contained in summary of care records received electronically (not eFax) without the need for manual entry?" Hospitals that responded "Yes, routinely" or "Yes, but not routinely" were designated as *integrating* information.

The final domain of interoperability is whether hospitals are *finding* patient information electronically. We define this measure using the question "Do providers at your hospital query electronically for patients' health information (e.g. medications, outside encounters) from sources outside your organization or hospital system?" Hospitals that responded "yes" to this question were designated as *finding* information.

2.2. Independent variables

Following prior literature, we specify a hospital's interoperability as a function of the following categories: information technology characteristics (EHR system capabilities, participation in national health network and HIO, having a dominant EHR vendor), organizational characteristics (system ownership, government, teaching, and not-for-profit), and local area characteristics (access to broadband internet and rurality).

The capabilities of EHR systems are captured by the number of functionalities. These included documentation of clinical notes, decision-support, and patient safety functionalities among others. We used a categorical variable to denote the number of functionalities in each EHR (21–25, 25–29, 30+). For sensitivity analyses we produced results from alternative specifications where EHRs were defined as basic or comprehensive[21] as well as the most generalizable form that identifies contribution of each EHR functionality to the interoperability gap. These results are similar to the ones presented and they are provided in the Appendix Table.

We included an indicator for a hospital's participation in networks that are national in scope. The national-level networks consist of CommonWell Health Alliance, Surescripts, Carequality, Digital Bridge, DirectTrust, e-Health Exchange, and Strategic Health Information Exchange Collaborative. We included measures for hospitals' participation in regional/state/local health information exchange organizations (HIOs).

Previous literature found that the market dominance of an EHR vendor was significantly associated with a hospital's interoperability. Following Everson and Adler-Milstein[17] we define market share of a dominant vendor within an HRR. We first used data from the 2016 HIMSS to identify the EHR vendors of all hospitals. In cases where information was missing or if a primary vendor could not be identified, we used data from the AHA or administrative data from the CMS EHR Incentive Program. Second, we calculated the market share of an EHR vendor to be the percent of hospitals using a particular vendor. The measure is weighted by hospital bed size. After calculating the market share of each vendor within an HRR, we identified the vendor with the highest market share within each HRR representing the dominant vendor.

Table 2
Estimates from Linear Probability Models based on the 2017 Sample of Pooled non-Federal Acute Care Hospitals.

	Find	Integrate	Send	Receive
Information Technology				
EHR Number of Functionalities				
< 21	Ref			
21–24	0.03 (0.04)	0.00 (0.04)	0.14 (0.03)	0.09* (0.04)
25–29	0.18**(0.03)	0.13** (0.03)	0.17** (0.02)	0.20** (0.03)
30+	0.24**(0.03)	0.24** (0.03)	0.19** (0.02)	0.24** (0.03)
National Networks Participation	0.07* (0.02)	0.20* (0.02)	0.10* (0.01)	0.13* (0.02)
State/Regional/local HIO	0.21** (0.02)	0.16** (0.02)	0.17** (0.01)	0.20** (0.02)
Dominant EHR Vendor	0.08** (0.02)	0.05* (0.02)	0.04** (0.01)	0.05* (0.02)
Organizational Characteristics				
Part of Hospital System	0.10** (0.02)	0.04 (0.02)	−0.02 (0.01)	0.05* (0.02)
Government Hospital	0.07* (0.03)	0.15* (0.03)	−0.03 (0.01)	0.00 (0.03)
Teaching Hospital	0.03 (0.02)	0.01 (0.02)	−0.00 (0.01)	0.02 (0.02)
Not-for-Profit Hospital	−0.02 (0.03)	0.11** (0.03)	−0.04* (0.02)	0.02 (0.02)
Local Area Characteristics				
% County Population without Broadband Access	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Rural Area Hospital Location	−0.07 (0.02)	−0.02 (0.02)	−0.01 (0.01)	−0.05* (0.01)
Constant	0.14** (0.04)	0.21**(0.04)	0.58**(0.03)	0.28**(0.04)
n	2789	2789	2789	2789

Note: Significantly different at **P < 0.01; *P < 0.05.
Source: Authors' calculation using 2017 AHA Annual Survey Health Information Technology Supplement.

Our model also includes indicators that capture organizational and area characteristics. The organizational characteristics include hospital's system membership, ownership type, teaching status, and non-profit status. Two measures capture area characteristics. The first, is the percentage of the population without access to broadband internet, a proxy for the health IT infrastructure, within a hospital's local area, which obtained from the Federal Communications Commission.[22] Second is the rurality of the hospital's location.

The decomposition analysis is conducted between two groups: 1) hospitals with less than 100 beds which we label as small and 2) hospitals with 100 beds or more which we label as large. Prior literature used the same threshold for identifying small hospitals.[16,23] These studies also identified medium hospitals with bed size between 100 and 500 beds and large hospitals with over 500 beds and found them to have similar rates of interoperability. Consequently, we grouped large and medium size hospitals and refer to the combined group as large hospitals.

3. Methods

We used the Blinder[19] – Oaxaca[18] decomposition technique to compute the contribution of each hospital characteristic to the differences in interoperability among hospital size. The method enables us to disaggregate the contribution of each characteristic into two components. The first component reflects the difference in the composition of hospital characteristics, which is usually referred to as the endowment effect. The second component represents the difference in returns to these characteristics. Specifically, we estimate the following expression:

$$\bar{y}^L - \bar{y}^S = \sum_{n=1}^{N} B_n^S(\bar{X}_n^L - \bar{X}_n^S) + \sum_{n=1}^{N} X_n^L(\bar{B}_n^L - \bar{B}_n^S) + (b_0^L - b_0^S) \quad (1)$$

where the superscripts L and S represent large and small hospitals, respectively. Subscript n indexes variables in vector X and Bs are estimates from the linear regression. The first component, $B_n^S(\bar{X}_n^L - \bar{X}_n^S)$ indicates contribution of hospital characteristics to the difference in the mean of outcome y, in this case, in each domain of interoperability. This effect measures the change in interoperability gap if, on average, small hospitals had characteristics of large hospitals. The second component, $X_n^L(\bar{B}_n^L - \bar{B}_n^S)$, represents the part of the difference in each domain of interoperability attributable to differences in returns of the characteristics. The second component measures the change in the interoperability gap if small hospitals had returns to the characteristics of the large hospitals.

We think both components provide valuable insights. If differences in returns are higher than differences in characteristics, it would indicate that large hospitals were able to use a particular technology more effectively than small hospitals. In other words, large hospitals derive higher returns from technologies. If differences in characteristics are higher than differences in returns of a characteristic, it would indicate that proportionately more large hospitals acquired a particular technology that contributes to the gap. In each case policy implications are different. Dominance of the characteristic effect would imply the importance of equipping small hospitals with a corresponding technologies for reducing the interoperability gap. Conversely, if returns to characteristics are larger, enabling small hospitals to use the technologies in the same manner as large would reduce the gap.

One of the limitations of our analysis is the absence of controls for omitted factors that may bias results. In particular, factors related to hospital's financial resources for IT operations, prevalence of interoperable exchange among hospital's referral partners, or hospital's inherent preferences for methods of exchange could be relevant in our application. In this context, the results of our analysis represent association and should be interpreted with caution. Given that a primary focus is decomposition, the potential biases are less of a concern if they operate in a similar manner for each hospital type.

Following previous studies[24,25] we restrict coefficients for the single categories to sum to zero which is implemented by transforming the categorical variables before model estimation so that our results would not depend on the choice of a reference group.

4. Results

4.1. Regression results

Table 2 presents results from linear regression identified on a pooled sample of all hospitals. Most of the findings are consistent with previous literature. A higher number of EHR functionalities increases a hospital's engagement in each of the interoperability domains. However, the effects are highly nonlinear. Having 20–24 functionalities does not impact finding and integrating data while having 30 or more functionalities increases these domains by over 24 percentage points. Participation in national networks and regional HIOs increases hospitals engagements in all domains of interoperability. Similarly, hospitals

Table 3
Decomposition results: Electronically find information and integrate summary of care records.

	Find		Integrate	
	Characteristics (SE)	Returns (SE)	Characteristics (SE)	Returns (SE)
Explained	0.18** (0.02)	0.04 (0.03)	0.17** (0.02)	−0.05 (0.03)
Detailed Decomposition				
EHR Functionalities	0.04** (0.01)	0.02 (0.01)	0.04** (0.01)	0.01 (0.01)
System Ownership	0.02** (0.01)	−0.04* (0.02)	−0.00 (0.01)	−0.04 (0.02)
National Network	0.02** (0.00)	−0.02 (0.02)	0.02** (0.01)	−0.05* (0.02)
HIO Participation	0.03** (0.01)	0.02 (0.02)	0.03 (0.01)	0.02 (0.02)
Dominant Vendor	0.01* (0.03)	−0.02 (0.01)	0.01* (0.00)	−0.00 (0.01)
Broadband	0.03 (0.02)	−0.04 (0.04)	−0.00 (0.03)	−0.01 (0.04)
Rural	0.03 (0.02)	0.01 (0.03)	0.05** (0.02)	−0.08** (0.03)
Other	0.00 (0.02)	−0.14** (0.05)	0.03 (0.01)	−0.17** (0.05)
Constant	–	0.25** (0.07)		0.27** (0.07)

Note: Significantly different at **P < 0.01; *P < 0.05. Other includes government, teaching and Not for Profit.
Source: Authors' calculation using 2017 AHA Annual Survey Health Information Technology Supplement.

that adopted dominant EHR vendors are more likely to perform each interoperability domain by four to eight percentage points.

4.2. Decomposition results

Table 3 shows the detailed decomposition results for electronically finding data and integrating summary of care records. The results of the table are estimated by equation (1), representing percentage point contribution of a particular variable(s) to the interoperability gap between two groups of hospitals - small (n = 1239) and large. The latter group consists of medium (n = 1170) and large (n = 380) bed size hospitals. The ratio of a specific contribution to the raw gap presented in Table 1 yields percent of the gap explained by this variable. The difference in characteristics contributes 18 percentage points to the gap in finding information which translates into explaining 82% (18 [Table 3]/22 [Table 1]) of the difference between small and large hospitals. The difference in returns is only four percentage points (18%) and is statistically insignificant. Similarly, for integrating data, characteristics contribute 17 percentage points to the gap while contribution of returns constitutes negative five percentage points but the latter effect is insignificant.

Among individual contributions, the number of EHR functionalities is the largest contributor in the case of electronically finding data and the second largest in the case of integrating data, explaining four percentage points in both cases. Differences in participation in a HIO and national network contribute two to three percentage points to finding data and integrating summary of care records, respectively, followed by differences in having a dominant vendor that contributes one percentage point. All three factors are statistically significant.

The results for electronically sending and receiving the data are slightly different from finding and integrating. Differences in characteristics explain 46 (5 [Table 4]/10.8 [Table 1]) percent and 68 (11 [Table 4]/16.2 [Table 1]) percent of the gap for sending and receiving summary of care records, respectively.

Among the individual contributions, having more EHR functionalities contributes two and four percentage points to the gap for sending and receiving domains, respectively. Participation in regional and national networks are also significant and contribute between one and three percentage points. However, having a dominant vendor is not a significant factor for these domains. One reason could be that sending and receiving are less complex and do not require the same EHR for these activities.

5. Discussion/conclusions

Currently, hospitals of different sizes experience significant differences in interoperability. This presents a challenge not only to achieving widespread interoperability but also potentially to providing equitable quality care across all segments of the population. In this paper, we explain what factors account for these differences, focusing on such characteristics as the advancement of hospital EHR systems, participation in HIOs and networks that are national in scope, and

Table 4
Decomposition results: Electronically send and receive summary of care records.

	Send		Receive	
	Characteristics (SE)	Returns (SE)	Characteristics (SE)	Returns (SE)
Explained	0.05** (0.01)	0.06** (0.02)	0.11** (0.02)	0.05** (0.02)
Detailed Decomposition				
EHR Functionalities	0.02** (0.00)	0.00 (0.01)	0.04** (0.06)	0.02 (0.01)
System Ownership	−0.01** (0.00)	−0.01 (0.02)	0.01 (0.01)	−0.01 (0.02)
National Network	0.01** (0.00)	−0.02 (0.02)	0.02** (0.00)	−0.01 (0.02)
HIO	0.02** (0.00)	−0.03 (0.02)	0.03** (0.01)	−0.00 (0.02)
Dominant Vendor	0.00 (0.00)	−0.02 (0.01)	0.00 (0.00)	−0.01 (0.01)
Broadband	−0.01 (0.01)	0.05 (0.02)	−0.05** (0.02)	0.09** (0.03)
Rural	0.01 (0.01)	−0.03 (0.03)	0.07** (0.02)	−0.06 (0.03)
Other	−0.00 (0.01)	−0.01 (0.03)	0.00 (0.01)	−0.11** (0.04)
Constant	–	0.12** (0.02)	–	0.15** (0.06)

Note: Significantly different at **P < 0.01; *P < 0.05. Other includes government, teaching and Not for Profit.
Source: Authors' calculation using 2017 AHA Annual Survey Health Information Technology Supplement.

dominance of EHR vendor. Our findings indicate that the total characteristics effect explains majority of the interoperability gap for integrating, finding and receiving domains, implying that, if on average, small hospitals had characteristics of large, the difference in each of these domains would be reduced by 50% or more.

The detailed analysis produced a number of important findings. First, the differences in the number of EHR functionalities were among the largest contributors to the interoperability gap. Specifically, EHRs functionalities explain 18, 32, 19, and 25% of the gap for finding, integrating, sending and receiving measures, respectively. Large hospitals are expending greater resources and effort to implement more advanced functionalities throughout all hospital departments. These efforts improve interoperability but they also create an interoperability gap between hospitals that are more resource constrained.

Second, the differences in participation in regional/state HIOs and networks that are national in scope significantly explain the interoperability gap. Each contributes up to three percentage points, explaining 24% of the gap between small and large hospitals. Participation in these networks is challenging due to the limited availability of operational HIOs nationwide and the costs associated with participation.

Having a dominant vendor within a hospital's HRR and being a system-owned hospital are significant factors in explaining the gap but to a lesser extent. Providers that use non-dominant vendors may face higher barriers to interoperability. Dominant vendors may have incentives to intentionally make HIE more difficult with other vendors' products to encourage use of its own products; a practice known as information-blocking.[26] However, other factors may be in play such as the lack of data standards, difficulties with patient matching, and minimal requirements for data integration.

Our results have important policy implications. Small and large hospitals derive similar benefits from the use of health IT infrastructure (e.g., participation in national networks and HIOs); however, differences in participation in these networks and adoption of more functionalities are significant factors in explaining the gap. This suggests that efforts taken to increase the adoption of technologies among smaller hospitals would reduce the gap. The Trusted Exchange Framework and Common Agreement[27] has the potential to reduce the number of different methods needed to electronically exchange health information, which could reduce the cost of exchange and improve interoperability of resource-constrained hospitals. The Promoting Interoperability Program[28] is an additional mechanism that could be used for improving interoperability of small hospitals by incentivizing functionalities directly related to interoperable exchange. The dominant vendor results indicate the existence of interconnectivity problems between vendors which place small hospitals at disadvantage. Policies that make stronger incentives for both vendors and providers to engage in cross-vendor exchange would be important for reducing interoperability differences.

Disclaimer

The views expressed in this paper are those of the authors, and no official endorsement by the Office of the National Coordinator for Health Information Technology, the Department of Health and Human Services, and The National Academies of Sciences, Engineering, and Medicine is intended or should be inferred.

The authors, Yuriy Pylypchuk, Vaishali Patel, Carla S. Alvarado, Talisha Searcy, declare no conflict of interest.

Appendix

Table 5
Total and EHR characteristics effects based on alternative definitions of EHR functionalities.

	Find (SE)	Integrate (SE)	Send (SE)	Receive (SE)
Basic and Comprehensive	0.04** (0.01)	0.05** (0.01)	0.01** (0.00)	0.03** (0.01)
All Functionalities	0.05** (0.01)	0.04** (0.01)	0.04** (0.00)	0.06** (0.01)

Note: *Significantly* different at **P < 0.01; *P < 0.05
Source: *Authors'* calculation using 2017 AHA Annual Survey Health Information Technology Supplement.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hjdsi.2019.04.001.

References

1. Henry J, Pylypchuk Y, Searcy T, Patel V. Adoption of electronic health record systems among US non-federal acute care hospitals: 2008-2015. *ONC Data Brief.* 2016;35:1–9.
2. Centers for Medicare & Medicaid. *MLN Booklet Critical Access Hospital.* U.S. Department of Health and Human Services; 2017.
3. American Hospital Association. *AHA Annual Survey Health Information Technology Supplement.* Association, A.H.; 2017.
4. Bennett KJ, Probst JC, Bullard JC, Crouch E. The importance of rural hospitals: transfers and 30-day readmissions among rural residents and patients presenting at rural hospitals. *Popul Health Manag.* 2018;22:120–126.
5. Nelson LF, Harland KK, Shane DM, Ahmed A, Mohr NM. Against the current: back-transfer as a mechanism for rural regionalization. *Am J Manag Care.* 2017;23:e287–e294.
6. Lichtman JH, Leifheit-Limson EC, Jones SB, Wang Y, Goldstein LB. Preventable readmissions within 30 days of ischemic stroke among Medicare beneficiaries. *Stroke.* 2013;44:3429–3435.
7. Lipsky MS, Glasser M. Critical access hospitals and the challenges to quality care. *J Am Med Assoc.* 2011;306:96–97.
8. Joynt KE, Harris Y, Orav EJ, Jha AK. Quality of care and patient outcomes in critical access rural hospitals. *Jama.* 2011;306:45–52.
9. Furukawa MF, Spector WD, Rhona Limcangco M, Encinosa WE. Meaningful use of health information technology and declines in in-hospital adverse drug events. *J Am Med Inform Assoc.* 2017;24:729–736.
10. Ross SE, Radcliff TA, LeBlanc WG, Dickinson LM, Libby AM, Nease Jr DE. Effects of health information exchange adoption on ambulatory testing rates. *J Am Med Inform Assoc.* 2013;20:1137–1142.
11. Stewart BA, Fernandes S, Rodriguez-Huertas E, Landzberg M. A preliminary look at duplicate testing associated with lack of electronic health record interoperability for transferred patients. *J Am Med Inform Assoc.* 2010;17:341–344.
12. American Hospital Association. The opportunities and challenges for rural hospitals in an era of health reform. *Trendwatch.* 2011:3 (April 2011).
13. Adler-Milstein J, Holmgren AJ, Kralovec P, Worzala C, Searcy T, Patel V. Electronic health record adoption in US hospitals: the emergence of a digital "advanced use" divide. *J Am Med Inform Assoc.* 2017;24:1142–1148.
14. Sandefer RH, Marc DT, Kleeberg P. Meaningful use attestations among US hospitals: the growing rural-urban divide. *Perspect. Health Inf. Manag.* 2015;12.
15. Koppel R, Lehmann CU. Implications of an emerging EHR monoculture for hospitals and healthcare systems. *J Am Med Inform Assoc.* 2014;22:465–471.
16. Holmgren AJ, Patel V, Charles D, Adler-Milstein J. US hospital engagement in core domains of interoperability. *Am J Manag Care.* 2016;22:e395–e402.
17. Everson J, Adler-Milstein J. Engagement in hospital health information exchange is associated with vendor marketplace dominance. *Health Aff.* 2016;35:1286–1293.
18. Oaxaca R. Male-female wage differentials in urban labor markets. *Int Econ Rev.* 1973:693–709.
19. Blinder AS. Wage discrimination: reduced form and structural estimates. *J Hum Resour.* 1973:436–455.

20. Rudin RS, Motala A, Goldzweig CL, Shekelle PG. Usage and effect of health information exchange: a systematic review. *Ann Intern Med.* 2014;161:803–811.
21. Jha AK, DesRoches CM, Campbell EG, et al. Use of electronic health records in US hospitals. *N Engl J Med.* 2009;360:1628–1638.
22. Federal Communications Commission. *Broadband Progress Report.* 2016; 2016.
23. Adler-Milstein J, Bates DW, Jha AK. US Regional health information organizations: progress and challenges. *Health Aff.* 2009;28:483–492.
24. Gardeazabal J, Ugidos A. More on identification in detailed wage decompositions. *Rev Econ Stat.* 2004;86:1034–1036.
25. Yun MS. A simple solution to the identification problem in detailed wage decompositions. *Econ Inq.* 2005;43:766–772.
26. Office of the National Coordinator for Health Information Technology. *Report on Health Information Blocking. Services.* 2015; 2015 Washington, DC.
27. Office of the National Coordinator for Health Information Technology. Draft. Trusted Exchange Network.
28. Centers for Medicare & Medicaid. *Promoting Interoperability.* 2018; 2018.