

# Health Information Exchange Among US Hospitals

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**T**he Health Information Technology for Economic and Clinical Health (HITECH) Act promotes the adoption of health information technology at an unprecedented level.<sup>1</sup> The bulk of funding is devoted to helping physicians and hospitals adopt and meaningfully use electronic health records (EHRs), structured as incentives of up to \$44,000 per provider for demonstrating meaningful use and then converting to penalties in 2015 if meaningful use is not achieved.<sup>1</sup> Substantial funding was also directed to support electronic health information exchange (HIE) at state and regional levels.<sup>2,3</sup> Health information exchange enables patients' health information to follow them between delivery settings in order to support care coordination and avoid duplication of services. There is broad consensus that such connectivity is critical to improving care and reducing healthcare costs. Nationwide health information exchange is a key driver of the efficiency gains promoted by health information technology (IT) advocates, including the widely publicized \$78 billion in annual savings.<sup>4</sup> Therefore, the success of HITECH hinges in part on whether it can jump-start historically low levels of HIE.<sup>5</sup>

The HITECH Act does not specify how HIE should be achieved, and as a result, an array of options are emerging. They range from the federally initiated Direct Project, a set of standards that allow senders to push health information securely to known receivers, to market-based HIE solutions that can be used to create an exchange network. Over the past decade, health information organizations (HIOs) have served as the primary mechanism by which the United States pursued clinical data exchange.<sup>6</sup> Health information organizations offer a particular approach to achieving HIE by bringing together stakeholders with clinical data (eg, physician practices, laboratories, hospitals) in a given geographic region and setting up the infrastructure for HIE. Since many HIOs are well established and have substantial experience supporting HIE, they appear likely to serve as a foundational approach under HITECH. For examples of HIO-based plans, see Colorado, Indiana, or New York at the State Health Information Exchange Program Web site.<sup>7</sup>

Health information organizations face challenges on multiple fronts, including a lack of funding, concerns about privacy and security, legal and regulatory challenges, technical challenges, and stakeholder concerns about

**Objectives:** To determine the proportion of US hospitals engaged in health information exchange (HIE) with unaffiliated providers and to identify key hospital-level and market-level factors associated with participating in exchange.

**Study Design:** Using the 2009 American Hospital Association Information Technology survey, supplemented by Dartmouth Atlas, Area Resource File, and other national data, we examined which hospitals participated in regional efforts to electronically exchange clinical data.

**Methods:** We used logistic regression models to determine hospital-level characteristics and market-level characteristics associated with hospitals' likelihood of participating in HIE.

**Results:** We found that 10.7% of US hospitals engaged in HIE with unaffiliated providers. In communities where exchange occurred, for-profit hospitals and those with a small market share were far less likely to engage in HIE than non-profit hospitals or those with a larger market share. Hospitals in more concentrated markets were more likely to exchange and hospitals in markets with higher Medicare spending were less likely to exchange.

**Conclusions:** At the start of implementation of the Health Information Technology for Economic and Clinical Health (HITECH) Act, only a small minority of US hospitals electronically exchange clinical data with unaffiliated providers. Health information exchange is a key part of reforming the healthcare system, and factors related to competitiveness may be holding some providers back.

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### Take-Away Points

Health information exchange (HIE), in which clinical data follow patients between delivery settings, is a critical component of reforming the healthcare system.

- Our findings suggest that hospital participation in HIE is low.
- Our work suggests that concerns related to competitiveness are playing a role, with for-profit hospitals and those with smaller market share less likely to participate.
- This low rate of participation is a challenge that will be encountered by federal policy makers as they design future stages of meaningful use incentives, as well as by states as they build out HIE capabilities.

competitiveness.<sup>8</sup> Health information organizations have also had to accommodate providers without EHRs, often by making data available on a portal that can disrupt work flow. The policy response has focused on securing funding—most recently in the form of large grants to states to increase HIE—as well as increasing EHR adoption and setting rules for data privacy, security, and technical standards.<sup>2</sup> Providers' concerns about the competitive implications of HIE, which have been documented in several case studies,<sup>9-12</sup> have received far less attention. In case studies, hospitals report that patient data tie both patients and providers to their institution, conferring a competitive advantage that would be lost by participating in an HIO.<sup>9,10</sup> Yet we know little about how broadly hospitals are engaged in HIE and whether certain key factors, especially those stemming from competitive concerns, are related to the decision to participate.

Therefore, we used nationally representative data to answer 3 questions. First, what proportion of US hospitals are exchanging clinical data with unaffiliated providers through an HIO (“engaging in HIE”)? Because the data were collected in the months after passage of HITECH, it offers a baseline against which national HIE progress can be measured. We focused on HIE taking place through HIOs because HIOs were the predominant strategy available when our data were collected and they are a key part of many states' plans for expanding HIE.<sup>7</sup> Second, are certain key hospital characteristics associated with the decision to engage in HIE? Specifically, we hypothesized that for-profit hospitals and hospitals with a small market share may be more concerned about loss of market share and therefore may be less likely to engage in HIE. Teaching hospitals, which routinely serve as referral hospitals, may be more likely to engage in HIE. Third, do features of healthcare markets where hospitals function affect the hospitals' likelihood of engaging in HIE? Specifically, we postulated that hospitals in more concentrated markets or those with less fragmentation of hospital care would be more likely to engage in HIE.

## METHODS

### Data

We used national data from the IT supplement to the an-

nual American Hospital Association (AHA) survey, which was administered during the spring and summer of 2009 to all acute-care hospitals, more than 95% of which were AHA member hospitals.<sup>13</sup> A total of 3725 member hospitals responded to the IT supplement survey (a response rate of 69%), and we limited our analytic sample to the 3101 acute-care, nonfederal hospitals located in the

50 states and the District of Columbia. We defined a market as a hospital referral region (HRR), a designation developed by the Dartmouth Atlas to define healthcare delivery markets based on Medicare beneficiary travel patterns for tertiary hospital care.<sup>14</sup>

The AHA IT supplement included 2 questions related to HIE: (1) whether the hospital participates in a regional HIO (or a regional HIO-like effort) to share electronic patient-level clinical data and (2) whether the hospital electronically exchanges each of 5 types of data (eg, laboratory reports, clinical care records) with hospitals or ambulatory providers that are part of a different system. (Original survey questions are included in **eAppendix 1**, available at [www.ajmc.com](http://www.ajmc.com).) We merged the IT supplement data with results from the annual AHA survey to develop measures at the market level as well as capture additional hospital characteristics. The Area Resource File, Medicare Provider and Analysis Review File, and Dartmouth Atlas were used for additional market level measures.

### Measures

**Outcome Measures.** We determined that a hospital engaged in HIE based on how it responded to the 2 HIE-related questions. Hospitals that (1) reported participating and actively exchanging data through a regional HIO (question 1) and (2) reported that they exchanged at least 1 type of clinical data with either hospitals or ambulatory providers that were part of a different system (question 2) were classified as participating in an HIO. Our approach helped ensure that the definition of HIO participation was consistent with the commonly held criteria that (1) HIE is actively occurring, (2) clinical data are exchanged, and (3) exchange takes place between organizations that are not part of the same system, which will be required under meaningful use.<sup>3,8</sup> Given that most HIOs are relatively new,<sup>5</sup> we did not require robust exchange (ie, multiple types of clinical data), though this is ultimately what is likely required to realize meaningful efficiency gains from HIE.

We identified markets with HIO presence as those in which at least 1 hospital in the HRR was classified as participating. We sought to validate hospitals' responses about participating in an HIO and exchanging data by examining a recently com-

pleted national survey of HIOs.<sup>5</sup> In this survey, HIOs were asked to identify the hospital service area(s) in which they functioned and actively facilitated clinical data exchange. We compared these areas with the areas in which hospitals reported participating in an HIO on the AHA IT supplement. We found substantial overlap, giving us confidence in the validity of hospitals' responses about HIO participation.

**Hospital Characteristics.** We examined 8 hospital characteristics, 3 of which were chosen a priori based on our hypotheses about which hospitals might or might not participate in an HIO: ownership (for profit, nonprofit private, or public), bed share in the market, and teaching status. The remaining characteristics were those that we thought might be directly related to participating or might confound the relationship between the 3 primary variables of interest (ownership, bed share, and teaching status) and participation: size, proportion of Medicaid admissions, whether the hospital was affiliated with a system, and whether the hospital had significant technological capability (a coronary care unit) and IT resources (an EHR).

**Market Characteristics.** We also examined a series of market-level characteristics. We created 2 measures to capture the competitiveness of the market. We measured market concentration using the Herfindahl-Hirschman Index. We measured market fragmentation as the proportion of discharged patients subsequently readmitted to a nonaffiliated hospital within the same market. Additional market-level measures included mean annual Medicare inpatient expenditures, mean proportion of hospitalizations from Medicare patients, urban/rural location, geographic region, managed care penetration, population density, percentage of the population that was uninsured, and per capita income. Each of these variables was chosen because we believed that it might be directly related to promoting HIE or might confound the relationship between the market variables of interest (market concentration and market fragmentation) and HIE. More details on why each measure was chosen and how it was defined are available in eAppendix 1.

**Analysis.** We first calculated an adjusted overall participation rate among all respondents in our sample. We used weights to adjust for potential nonresponse bias after finding modest but significant differences when comparing respondents and nonrespondents to the survey (eAppendix 2, available at [www.ajmc.com](http://www.ajmc.com)). We next examined whether our hypothesized hospital characteristics were related to a hospital's decision to participate in an HIO. We started with bivariate relationships and then built multivariable logistic regression models with hospital-level sampling weights and robust standard errors adjusted for clustering at the market level. Our analyses compared hospitals that participated in

HIOs with those that did not *within HRRs that had an HIO*. Looking within the 165 HRRs (54%) with an HIO helped to ensure that hospitals had an opportunity to participate. We next examined whether our hypothesized market characteristics were related to hospital participation by adding market-level measures to the multivariable logistic regression model.

We ran a set of sensitivity analyses to assess the robustness of our findings. We assessed whether our results held when we used bed share at the system level within the market. In addition, we substituted our measure of the hospital Herfindahl-Hirschman Index for the hospital-system Herfindahl-Hirschman Index in our market characteristics model. These values could serve as better measures of competitive position and concentration in markets in which systems behave cooperatively. To assess whether unobserved market-level characteristics affected hospital-level results, we ran our hospital characteristics model using market conditional fixed effects. Finally, we used an alternative specification of the dependent variable that relied only on the AHA IT supplement question about hospital participation in a regional HIO and not the additional question about types of data exchanged. This approach likely included hospitals participating in regional HIOs focused on nonclinical data exchange or regional HIOs supporting data exchange between hospitals and other providers (eg, public health departments).

## RESULTS

### Characteristics of Hospitals in the AHA IT Survey

Hospitals in our sample were primarily small and medium in size (46% and 42%, respectively; **Table 1**). They were most often nonprofit hospitals (64%) and just over a quarter were teaching hospitals. Approximately half of the respondents were members of a hospital system and the majority were located in an urban area (73%). While more than a third of respondents had a cardiac intensive care unit, only 16% had at least a basic EHR.

### Hospitals That Participate in HIOs

We found that 10.7% of hospitals participated in a regional HIO. In bivariate analysis, for-profit hospitals were less likely than their nonprofit counterparts to participate (7% vs 18%,  $P < .001$ ; **Table 2**). Hospitals with a more dominant market share were more likely to participate: while only 9% of hospitals in the lowest quartile of market share participated, 27% of hospitals in the highest quartile did so ( $P < .001$  across the 4 quartiles). Finally, we found that major teaching hospitals were more likely to participate in a regional HIO than minor teaching hospitals or nonteaching institutions. Multivariate results were similar: for-profit hospitals were far less likely to participate in a regional HIO (odds ratio [OR] 0.35;

■ **Table 1.** Hospital Characteristics (N = 3101)<sup>a</sup>

Characteristic	Respondents
	No (%)
<b>Size</b>	
Small (6-99 beds)	1438 (46)
Medium (100-399 beds)	1290 (42)
Large (≥400 beds)	350 (11)
<b>Profit status</b>	
For profit	313 (10)
Nonprofit	1973 (64)
Public	792 (26)
<b>Teaching status</b>	
Major	221 (7)
Minor	589 (19)
<b>Member of hospital system</b>	1609 (52)
<b>Urban location</b>	2267 (73)
<b>Dedicated cardiac ICU</b>	1071 (35)
<b>Region</b>	
Northeast	418 (13)
Midwest	1053 (34)
South	1089 (35)
West	518 (17)
<b>Had at least basic EHR</b>	502 (16)
<small>EHR indicates electronic health record; ICU, intensive care unit.  <sup>a</sup>Limited to American Hospital Association Information Technology Supplement respondents.</small>	

$P = .012$ ), as were hospitals with a lower market share (Table 3). However, major teaching hospitals were no more likely to participate than minor teaching hospitals or nonteaching hospitals. We found 1 other characteristic that was associated with participation: whether the hospital had at least a basic EHR. Hospitals with an EHR were significantly more likely to participate (OR 1.76;  $P = .002$ ).

### Market Characteristics Associated With HIO Participation

Hospitals in the most concentrated markets (those in the top quartile of the Herfindahl-Hirschman Index) had 2.88 greater odds of participating (95% confidence interval [CI] 1.48-5.59) compared with the least concentrated markets ( $P = .015$  across the 4 quartiles; Table 4). Hospitals in markets with higher Medicare spending were less likely to participate: those in the top quartile of spending had 66% lower odds of participating (95% CI 0.23-0.83) compared with the lowest spending markets ( $P = .018$ ). We did not find a significant difference in hospital participation based on the degree of market fragmentation.

### Sensitivity Analyses

Our multivariate results did not meaningfully differ when we examined bed share at the system level in the model with hospital-level characteristics (eAppendix 4, available at [www.ajmc.com](http://www.ajmc.com)). Our market-level results were also very similar when we examined the system-level Herfindahl-Hirschman Index: hospitals were still more likely to participate in more concentrated markets (eAppendix 5, available at [www.ajmc.com](http://www.ajmc.com)). When we ran our hospital-level multivariate model using conditional fixed effects at the market level, we generally found results consistent with our model that included specific market-level characteristics. The 1 exception was hospital bed share, which with the addition of market fixed effects was no longer associated with likelihood of participating in HIE (eAppendix 6, available at [www.ajmc.com](http://www.ajmc.com)). Finally, our results were largely unchanged when we only required hospitals to report participating in a regional HIO, relaxing the requirement to exchange specific types of data (eAppendix 7, available at [www.ajmc.com](http://www.ajmc.com)).

## DISCUSSION

Our nation has embarked on an ambitious strategy to promote the adoption of health IT and electronic exchange of clinical data. Using nationally representative data, we found that only 1 in 9 US hospitals was sharing at least 1 type of clinical data through an HIO in 2009. Our study also suggests that key market forces are likely shaping hospitals' decisions to participate in an HIO. Hospitals with a dominant market share may perceive participation as an opportunity, while for-profit hospitals and those with small market share have mostly opted out. Hospitals in more concentrated markets were more likely to participate, while hospitals in markets with high Medicare spending were less likely to participate. In addition, just over half the markets had an HIO, highlighting substantial gaps in HIE coverage at the start of HITECH.

We expected that competition might be an important force dampening the enthusiasm for regional HIO participation, but we were surprised at how prominently it appeared among both hospital and market characteristics. For-profit institutions as well as those with smaller market share had dramatically lower participation rates in regional HIOs. For-profit hospitals may be more sensitive to concerns about potential loss of market share than nonprofit hospitals, and those with

a smaller market share may be less able to tolerate further patient erosion by participating in an effort that facilitates patients seeing other providers. Within more concentrated markets, hospital participation rates are higher, providing further support for the role of competition. These results suggest that concerns about competition and loss of market share may need to be addressed in order for HIE efforts to achieve broad penetration.

One interesting finding was that hospitals in higher Medicare spending regions were less likely to participate in clinical data exchange through a regional HIO. It is possible that greater exchange of clinical data has led to a reduction in Medicare spending, though we think this is unlikely because most of these HIOs are relatively new and the breadth of clinical data exchanged is relatively narrow. An alternative explanation is that low-spending regions have the kind of medical culture that fosters greater collaboration and sharing, which also drives willingness to share clinical data exchange in these communities. Unfortunately, our cross-sectional analyses do not allow us to establish causal relationships. As a result, the mechanisms underlying our results are largely speculative.

Although we are unaware of any large-scale empirical work focused on competition and providers' choice to participate in HIE, there has been important work in this area. In case studies, Grossman and colleagues found that patients and their data were perceived to confer a competitive advantage that would be lost by participating in a regional HIO.<sup>10</sup> This was particularly salient for hospitals who viewed clinical data as "a key strategic asset, tying physicians and patients to their organization."<sup>10</sup> Other case studies have found similar results.<sup>9,11,12</sup> Our study extends these findings by empirically examining them in a national sample of hospitals.

Our findings have important policy implications. Given that the first stage of meaningful use only requires the *capability* to exchange clinical data, it is unlikely that the requirements in and of themselves will overcome issues of competitiveness that might be holding some providers back. States, the primary recipients of federal support to expand HIE, may want to consider how to address such barriers. Beyond existing efforts to promote EHR adoption, they could focus on facilitating exchange of data with the greatest financial

**Table 2.** Hospital Participation in Regional Health Information Organizations: Hospital Characteristics<sup>a</sup>

Characteristic	Participates in HIO (N = 344; 10.7%)	
	No (%)	P
<b>Primary Characteristics of Interest</b>		
<b>Profit status</b>		
Private, nonprofit	1402 (18)	<.001
For profit	203 (7)	
Public	554 (14)	
<b>Percentage of bed share in market</b>		
First quartile—lowest percentage	(9)	<.001
Second quartile	(12)	
Third quartile	(17)	
Fourth quartile—highest percentage	(27)	
<b>Teaching status</b>		
Nonteaching	1565 (14)	<.001
Minor teaching	440 (19)	
Major teaching	177 (27)	
<b>Other Characteristics Examined</b>		
<b>Hospital size</b>		
Small	997 (12)	<.001
Medium	910 (17)	
Large	252 (26)	
<b>Presence of cardiac ICU</b>		
Yes	772 (20)	<.001
No	1387 (14)	
<b>System affiliation</b>		
Yes	1121 (17)	.283
No	1061 (15)	
<b>Percentage of Medicaid admissions</b>		
First quartile—lowest percentage	(14)	.558
Second quartile	(17)	
Third quartile	(16)	
Fourth quartile—highest percentage	(17)	
<b>EHR system</b>		
Had no EHR	1828 (14)	<.001
Had at least basic EHR	354 (25)	
EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit. <sup>a</sup> Limited to hospitals in markets with regional health information organization presence. Basic EHR excludes physician notes functionality.		

benefits for providers (mainly laboratory and radiology tests). Such an effort would likely entice more providers to join in, although such an approach is not without costs: by narrowing its focus, these HIOs would simultaneously reduce the societal

■ **Table 3.** Adjusted Likelihood of Participation in Regional Health Information Organization: Hospital Characteristics<sup>a</sup>

Characteristic	Participates in HIO		P
	Odds Ratio	95% Confidence Interval	
<b>Primary Characteristics of Interest</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.35	0.19-0.66	.012
Public	0.86	0.62-1.18	
<b>Market position</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	1.44	0.93-2.25	<.001
Quartile 3	2.00	1.31-3.06	
Quartile 4—highest bed share	3.64	2.21-5.98	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	0.94	0.67-1.32	.480
Major teaching	1.09	0.68-1.75	
<b>Other Characteristics Examined</b>			
<b>Hospital size</b>			
Small	Reference		
Medium	0.88	0.62-1.25	.770
Large	0.85	0.47-1.52	
<b>Presence of cardiac ICU</b>	1.01	0.74-1.36	.964
<b>System affiliated</b>	1.22	0.94-1.60	.137
<b>Medicaid admissions</b>			
Quartile 1—lowest percentage	Reference		
Quartile 2	1.02	0.72-1.45	.948
Quartile 3	0.93	0.65-1.33	
Quartile 4—highest percentage	0.96	0.62-1.47	
<b>Had at least basic EHR</b>	1.76	1.24-2.50	.002

EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit.

<sup>a</sup>Limited to hospitals in markets with HIO presence.

value of HIE. Whether HIE efforts would then be able to expand to include a more comprehensive set of data is unclear.

In future meaningful use regulations, the Centers for Medicare & Medicaid Services is signaling that it will require hospitals to exchange a robust set of clinical data, although it will likely leave the channels through which those data are shared up to individual providers. While such an approach might spur some hospitals to join state-sponsored HIOs and share data more widely, others might strategically share data with only a subset of providers in the market (eg, referring physicians, nursing homes), creating potentially greater market fragmentation with islands of HIE that effec-

tively lock patients into a group of providers. Policy makers will likely need strong incentives, financial or otherwise, to overcome these market pressures that many hospitals feel. One approach may be stronger penalties than those currently tied to meaningful use for not engaging in broad exchange, which could act as an opposing competitive pressure by directly threatening hospitals' financial viability. These stronger tactics may only be needed in the short term, however, because once robust HIE reaches a critical threshold, hospitals' competitive position may be more harmed by opting out. The key challenge for policy makers is getting the country to this tipping point.

**Table 4.** Adjusted Likelihood of Participation in Regional Health Information Organization: Hospital and Market Characteristics<sup>a</sup>

Characteristic	Participates in HIO		P
	Odds Ratio	95% Confidence Interval	
<b>Primary Characteristics of Interest: Hospital</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.32	0.16-0.63	.010
Public	0.83	0.59-1.18	
<b>Market position</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	1.26	0.79-2.00	.223
Quartile 3	1.48	0.89-2.46	
Quartile 4—highest bed share	2.13	1.04-4.40	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	1.17	0.80-1.69	.111
Major teaching	1.74	0.97-3.15	
<b>Primary Characteristics of Interest: Market</b>			
<b>Market concentration</b>			
Quartile 1—least concentrated	Reference		
Quartile 2	1.15	0.78-1.69	.015
Quartile 3	1.40	0.83-2.34	
Quartile 4—most concentrated	2.88	1.48-5.59	
<b>Market fragmentation</b>			
Quartile 1—least fragmentation	Reference		
Quartile 2	1.38	0.91-2.11	.125
Quartile 3	0.87	0.52-1.44	
Quartile 4—most fragmentation	1.22	0.70-2.11	
<b>Market Medicare spending</b>			
Quartile 1—lowest spending	Reference		
Quartile 2	0.93	0.54-1.60	.018
Quartile 3	0.65	0.40-1.10	
Quartile 4—highest spending	0.44	0.23-0.83	

HIO indicates health information organization.

<sup>a</sup>Limited to hospitals in markets with HIO presence. Full model results can be found in eAppendix 3 at [www.ajmc.com](http://www.ajmc.com).

**Limitations**

There are important limitations to our work. First, the AHA IT supplement is self reported and we were unable to verify accuracy of responses. However, we validated the data when we could by comparing markets with HIO presence as identified by the AHA IT supplement with an independent source of data on where HIOs operate.<sup>5</sup> Second, although the response rate to the hospital IT supplement was high (69%), and we statistically adjusted for nonresponse, some degree of nonresponse bias likely remains. Our findings may also be af-

ected by omitted variable bias. While we attempted to include a comprehensive set of variables, there are some that we were unable to measure. For example, we lacked a direct measure of hospitals’ financial health as well as the overall financial health of a market, which may influence hospital participation, although we included a set of proxy measures as covariates. The proxy measures did not provide consistent evidence of a relationship between participation and financial health of either the hospital itself or the market in which it operates.

More broadly, this is exploratory work in a rapidly changing, complex field. While our findings suggest that competition plays a role, a multitude of other factors that affect HIO participation need to be examined, and we were not able to determine the extent to which competition plays a role relative to other potential barriers. With limited empirical evidence on the benefits of HIOs, it may be that these organizations are still early in the innovation adoption cycle, and the majority of hospitals are waiting to see how early adopters fare. In addition, because we could not examine specific HIOs and their characteristics, we were unable to account for governance approach, technical architecture, types of stakeholders involved, and other considerations that undoubtedly influence hospital participation decisions.

Finally, we were not able to assess causality and suggest that future work should rely on longitudinal data in order to more directly assess the direction of the relationship between hospital and market characteristics and HIE. However, hospital characteristics are quite stable, and, given that most HIOs are relatively new,<sup>15</sup> we think it is unlikely that they have had the opportunity to shift hospital market share or market competitiveness.

## CONCLUSIONS

We report the first set of national data on the number of US hospitals participating in HIE through HIOs at the start of HITECH and found that approximately 1 in 9 hospitals were engaged. In this national sample, we also found that a hospital's ownership status and its market share were associated with its decision to participate in HIE. At both the market and hospital level, our findings suggest that concerns about the competitive implications of HIE may be playing a role. It is unclear whether the potency of the current financial and regulatory incentives will be adequate to coax US hospitals to share their clinical data with other providers, many of whom may be perceived as competitors.

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**■ eAppendix 1.** Subset of American Hospital Association Information Technology Supplement Questions With Additional Details on Key Measures

**Information Technology Supplement Questions**

**1. Does your hospital participate in any regional arrangements to share electronic patient-level clinical data through an electronic health information exchange, such as an RHIO (Regional Health Information Organization)?**

- Participate, we actively exchange data
- Participate, but we DO NOT exchange data
- We do not participate in any regional arrangements for electronic health information exchange

**2. Does your hospital electronically exchange any of the following patient data with any of the providers listed below? (Check all that apply.)**

	(1) With Hospitals in Your System	(2) With Hospitals Outside Your System	(3) With Ambulatory Providers Outside Your System
a. Patient demographics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Clinical care record (clinical history, exam)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Laboratory results	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Medication history	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Radiology reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Additional Details on Key Measures**

**Hospital-Level Measures**

**Profit status**—This American Hospital Association (AHA) measure included the following categories: for profit, non-profit private, and public.

**Bed share**—We calculated this measure from the AHA data by dividing the given hospital’s beds by the total number of beds in the market.

**Teaching status**—This measure was constructed from AHA data and designated hospitals that were members of the council of teaching hospitals, had an approved residency program, or had a resident per bed ratio greater than zero.

**Size**—This AHA measure included the following categories: fewer than 100 beds, 100-399 beds, and 400 or more beds.

**Electronic health record**—Our measure of whether a hospital had an electronic health record was derived from the AHA Information Technology supplement and relied on the definition of a “basic” system developed by Jha et al, which required 8 functionalities in at least 1 major clinical unit (eg, the intensive care unit).<sup>1</sup>

**Proportion of hospitalizations from Medicaid patients**—This AHA measure captures the percentage of the hospital’s admissions that came from Medicaid patients.

**Cardiac intensive care unit, system affiliated**—These are dichotomous AHA measures that indicate whether the hospital has a cardiac intensive care unit or is affiliated with a system.

**Market-Level Measures**

**Concentration: Herfindahl-Hirschman Index**—This measure was constructed from AHA data by squaring and then summing the bed share of each hospital in the market. While there are alternative measures of market concentration available, Wong et al found that empirical studies of hospital behavior are insensitive to the choice of measure.<sup>2</sup>

**Fragmentation**—We created this measure using the 2006 Medicare Provider Analysis and Review data set with complete claims for all inpatients enrolled in the Medicare fee-for-service plan. We calculated the proportion of patients in the hospital referral region (HRR) with an index hospitalization during the first 6 months who had a subsequent readmission within the next 6 months to at least 1 other unaffiliated hospital in the same HRR. We excluded those under age 65 years or those transferred between hospitals. Our measure is consistent with the recommendations of a recent evidence review on valid and reliable measurement of care continuity.<sup>3</sup>

**Teaching hospital penetration**—This measure was constructed from AHA data by calculating the percentage of hospitals in the market that were members of the council of teaching hospitals, had an approved residency program, or had a resident per bed ratio greater than zero. We included this measure under the assumption that these organizations may have the leadership and stature within the market to drive regional health information organization (HIO) formation.

(Continued)

■ **eAppendix 1.** Subset of American Hospital Association Information Technology Supplement Questions With Additional Details on Key Measures (*Continued*)

The following covariates were included to adjust for the financial health of the market and associated ability to support a regional HIO:

1. **Mean proportion of hospitalizations from Medicare patients.** This variable was calculated from AHA data by averaging the percentage of Medicare admissions across the hospitals in the market.
2. **Mean annual Medicare inpatient expenditures in the HRR.** This measure was from the Dartmouth Atlas (2007), which calculates mean Part A Medicare spending for beneficiaries within each HRR.
3. **Percentage of population uninsured and per capita income.** These variables came from the Area Resource File and were available at the county level. We used zip codes to create unweighted averages at the HRR level.

The following covariates were included to capture the need for health information exchange in the market:

1. **Urban/rural location and geographic region.** These variables came from the AHA annual survey and capture whether the market is located in an urban area and the 4 census regions.
2. **Population density and managed care penetration.** These variables came from the Area Resource File and were calculated using the same approach described for other Area Resource File measures.

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## HIE Among US Hospitals

### ■ eAppendix 2. Characteristics of Hospitals Sampled, Respondents, and Nonrespondents<sup>a</sup>

Characteristic	All Hospitals (N = 4493), %	Responding Hospitals (n = 3101), %	Nonresponding Hospitals (n = 1392), %	P
<b>Size</b>				
Small (<100 beds)	48	46	49	<.001
Medium (100-399 beds)	43	42	44	
Large (≥400 beds)	10	12	7	
<b>Region</b>				
Northeast	13	13	12	<.001
Midwest	30	34	21	
South	38	35	43	
West	19	17	24	
<b>Ownership</b>				
Private, nonprofit	61	64	53	
For profit	15	10	25	<.001
Public	24	26	22	
<b>Major teaching hospital</b>	24	26	18	.003
<b>Urban location</b>	56	54	59	<.001
<b>Member of a system</b>	55	52	63	<.001
<sup>a</sup> Source: authors' analysis.				

■ **eAppendix 3.** Adjusted Likelihood of Participation in Regional Health Information Organization—Hospital and Market Characteristics: Complete Model Results<sup>a</sup>

Participates in HIO				Participates in HIO			
Characteristic	Odds Ratio	95% Confidence Interval	P	Characteristic	Odds Ratio	95% Confidence Interval	P
<b>Primary Characteristics of Interest: Hospital</b>				<b>Other Market Characteristics</b>			
<b>Ownership</b>				<b>Market Medicare admissions</b>			
Private, nonprofit	Reference			Quartile 1—lowest percentage of admissions	Reference		
For profit	0.32	0.16-0.63	.010	Quartile 2	1.58	1.04-2.40	.167
Public	0.83	0.59-1.18		Quartile 3	1.47	0.88-2.45	
<b>Market position</b>				Quartile 4—highest percentage of admissions			
Quartile 1—lowest bed share	Reference				1.46	0.70-3.04	
Quartile 2	1.26	0.79-2.00	.223	<b>Market teaching hospital penetration</b>			
Quartile 3	1.48	0.89-2.46		Quartile 1—lowest percentage of teaching hospitals			
Quartile 4—highest bed share	2.13	1.04-4.40		Quartile 2	Reference		
<b>Teaching status</b>				Quartile 3			
Nonteaching	Reference			Quartile 4—highest percentage of teaching hospitals	1.70	1.11-2.60	.057
Minor teaching	1.17	0.80-1.69	.111		0.96	0.57-1.60	
Major teaching	1.74	0.97-3.15		<b>Urban</b>			
<b>Other Hospital Characteristics</b>				1.16			
<b>Hospital size</b>				<b>Market region</b>			
Small	Reference			Northeast	Reference		
Medium	1.04	0.69-1.56	.980	Midwest	0.67	0.39-1.13	.133
Large	1.04	0.55-1.97		South	1.02	0.47-2.19	
<b>Presence of cardiac ICU</b>				West			
	0.96	0.69-1.32	.784		1.22	0.64-2.30	
<b>System affiliated</b>				<b>Market managed care penetration</b>			
	1.38	1.04-1.84	.026	Quartile 1—lowest HMO penetration			
<b>Medicaid admissions</b>				Reference			
Quartile 1—lowest percentage	Reference			Quartile 2	1.28	0.72-2.28	.642
Quartile 2	0.92	0.66-1.26	.751	Quartile 3	1.26	0.66-2.43	
Quartile 3	0.83	0.58-1.17		Quartile 4—highest HMO penetration			
Quartile 4—highest percentage	0.94	0.62-1.42			1.66	0.76-3.62	
<b>Had at least basic EHR</b>				<b>Market population density</b>			
	1.56	1.10-2.23	.013	Quartile 1—lowest population density			
<b>Primary Characteristics of Interest: Market</b>				Reference			
<b>Market concentration</b>				Quartile 2			
Quartile 1—least concentrated	Reference			Quartile 3	1.00	0.58-1.72	.795
Quartile 2	1.15	0.78-1.69	.015	Quartile 4—highest population density	1.20	0.61-2.35	
Quartile 3	1.40	0.83-2.34			0.89	0.37-2.14	
Quartile 4—most concentrated	2.88	1.48-5.59		<b>Market percentage of population uninsured</b>			
<b>Market fragmentation</b>				Quartile 1—lowest percentage of uninsured			
Quartile 1—least fragmentation	Reference			Quartile 2	Reference		
Quartile 2	1.38	0.91-2.11	.125	Quartile 3	0.81	0.48-1.37	.115
Quartile 3	0.87	0.52-1.44		Quartile 4—highest percentage of uninsured	0.47	0.23-0.97	
Quartile 4—most fragmentation	1.22	0.70-2.11			0.72	0.33-1.59	
<b>Market Medicare spending</b>				<b>Market per capita income</b>			
Quartile 1—lowest spending	Reference			Quartile 1—lowest per capita income			
Quartile 2	0.93	0.54-1.60	.018		Reference		
Quartile 3	0.65	0.40-1.10		Quartile 2	0.42	0.23-0.77	.018
Quartile 4—highest spending	0.44	0.23-0.83		Quartile 3	0.63	0.34-1.15	
				Quartile 4—highest per capita income	0.75	0.33-1.73	

EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit.

<sup>a</sup>Limited to hospitals in markets with HIO presence. Source: authors' analysis.

## HIE Among US Hospitals

### ■ eAppendix 4. Adjusted Likelihood of Participation in Regional Health Information Organization: Market Position at System Level<sup>a</sup>

Characteristic	Participates in HIO		
	Odds Ratio	95% Confidence Interval	P
<b>Primary Characteristics of Interest</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.40	0.21-0.77	.032
Public	0.87	0.63-1.21	
<b>Market position—system</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	1.75	1.11-2.78	.002
Quartile 3	2.03	1.29-3.20	
Quartile 4—highest bed share	2.84	1.64-4.91	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	0.98	0.70-1.37	.52
Major teaching	1.12	0.70-1.80	
<b>Other Hospital Characteristics</b>			
<b>Hospital size</b>			
Small	Reference		
Medium	1.08	0.76-1.54	.674
Large	1.26	0.75-2.14	
<b>Presence of cardiac ICU</b>	1.07	0.79-1.46	.640
<b>System affiliated</b>	0.90	0.64-1.26	.531
<b>Medicaid admissions</b>			
Quartile 1—lowest percentage	Reference		
Quartile 2	1.14	0.81-1.61	.836
Quartile 3	1.01	0.70-1.45	
Quartile 4—highest percentage	1.05	0.69-1.60	
<b>Had at least basic EHR</b>	1.70	1.19-2.43	.003

EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit.  
<sup>a</sup>Limited to hospitals in markets with HIO presence. *Source:* authors' analysis.

■ **eAppendix 5.** Adjusted Likelihood of Participation in Regional Health Information Organization—Hospital and Market Characteristics: Market Position and Concentration at System Level<sup>a</sup>

Characteristic	Participates in HIO		
	Odds Ratio	95% Confidence Interval	P
<b>Hospital Characteristics</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.36	0.18-0.72	.026
Public	0.83	0.58-1.17	
<b>Market position—system</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	1.46	0.88-2.40	.414
Quartile 3	1.43	0.82-2.48	
Quartile 4—highest bed share	1.66	0.88-3.13	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	1.25	0.86-1.80	0.078
Major teaching	1.94	1.09-3.46	
<b>Market-Level Characteristics</b>			
<b>Market concentration—system</b>			
Quartile 1—least concentrated	Reference		
Quartile 2	1.87	1.21-2.87	.002
Quartile 3	1.56	0.92-2.65	
Quartile 4—most concentrated	2.55	1.46-4.44	
<b>Market fragmentation</b>			
Quartile 1—least fragmentation	Reference		
Quartile 2	1.38	0.87-2.18	.092
Quartile 3	0.81	0.45-1.47	
Quartile 4—most fragmentation	1.08	0.60-1.95	
<b>Market Medicare spending</b>			
Quartile 1—lowest spending	Reference		
Quartile 2	0.97	0.58-1.61	.033
Quartile 3	0.65	0.42-1.02	
Quartile 4—highest spending	0.53	0.31-0.91	

HIO indicates health information organization.  
<sup>a</sup>Limited to hospitals in markets with HIO presence. *Source:* authors' analysis.

## HIE Among US Hospitals

### ■ eAppendix 6. Adjusted Likelihood of Participation in Regional Health Information Organization: Market Fixed Effects<sup>a</sup>

Characteristic	Participates in HIO		P
	Odds Ratio	95% Confidence Interval	
<b>Primary Characteristics of Interest</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.45	0.24-0.83	.045
Public	0.89	0.62-1.28	
<b>Market position</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	0.97	0.61-1.54	.900
Quartile 3	0.99	0.55-1.78	
Quartile 4—highest bed share	1.16	0.52-2.59	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	1.10	0.76-1.59	.434
Major teaching	1.37	0.75-2.50	
<b>Other Hospital Characteristics</b>			
<b>Hospital size</b>			
Small	Reference		
Medium	1.47	0.92-2.35	.210
Large	1.93	0.89-4.15	
<b>Presence of cardiac ICU</b>	1.07	0.78-1.46	.679
<b>System affiliated</b>	1.44	1.08-1.94	.014
<b>Medicaid admissions</b>			
Quartile 1—lowest percentage	Reference		
Quartile 2	0.89	0.62-1.30	.674
Quartile 3	0.79	0.54-1.17	
Quartile 4—highest percentage	0.82	0.55-1.21	
<b>Had at least basic EHR</b>	1.67	1.2-2.31	.002

EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit.

<sup>a</sup>Limited to hospitals in markets with HIO presence. *Source:* authors' analysis.

■ **eAppendix 7.** Adjusted Likelihood of Participation in Regional Health Information Organization: Alternative Dependent Variable<sup>a</sup>

Characteristic	Participates in HIO		
	Odds Ratio	95% Confidence Interval	P
<b>Primary Characteristics of Interest</b>			
<b>Ownership</b>			
Private, nonprofit	Reference		
For profit	0.60	0.40-0.91	.222
Public	0.82	0.61-1.11	
<b>Market position</b>			
Quartile 1—lowest bed share	Reference		
Quartile 2	1.49	1.08-2.06	.009
Quartile 3	1.68	1.14-2.46	
Quartile 4—highest bed share	2.10	1.36-3.24	
<b>Teaching status</b>			
Nonteaching	Reference		
Minor teaching	0.87	0.65-1.17	.076
Major teaching	1.23	0.83-1.83	
<b>Other Hospital Characteristics</b>			
<b>Hospital size</b>			
Small	Reference		
Medium	0.96	0.70-1.30	.878
Large	0.88	0.53-1.46	
<b>Presence of cardiac ICU</b>	1.05	0.81-1.36	.689
<b>System affiliated</b>	1.48	1.18-1.85	.001
<b>Medicaid admissions</b>			
Quartile 1—lowest percentage	Reference		
Quartile 2	0.90	0.67-1.21	.911
Quartile 3	0.97	0.73-1.28	
Quartile 4—highest percentage	0.95	0.69-1.29	
<b>Had at least basic EHR</b>	1.49	1.12-1.98	.006

EHR indicates electronic health record; HIO, health information organization; ICU, intensive care unit.  
<sup>a</sup>Limited to hospitals in markets with HIO presence. *Source:* authors' analysis.