

US Hospital Engagement in Core Domains of Interoperability

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Following the large increase in electronic health record (EHR) adoption in US hospitals over the past 6 years,¹ attention is increasingly focused on ensuring that EHRs can exchange and integrate patient data. Interoperability is expected to generate substantial gains in quality and efficiency by reducing redundant care² and improving care coordination through better frontline clinician access to information.³ It is also expected to be a key enabler of population-based payment and care delivery reform models through data aggregation⁴ and information technology (IT)-enabled performance measurement.⁵ In response, both the public^{6,7} and private sector⁸ are devoting substantial resources to increase interoperability by enhancing technical capabilities, as well as by addressing governance, financial, and policy issues.

In order to track progress and inform policy efforts, it is critical to assess where we stand today.⁹ Prior research has tracked EHR adoption over time and found that hospital characteristics, such as size, location, and ownership, are associated with adoption.¹ A related set of studies have examined hospital characteristics associated with engaging in specific forms of electronic health information sharing; for example, private nonprofit hospitals and hospitals that were part of a healthcare system were more likely to participate in a community or Regional Health Information Organization (RHIO).¹⁰ A key difference between the 2 literatures is that the former uses a functionality-based, technology-agnostic definition of EHRs to assess adoption patterns,^{1,11} whereas the latter has lacked such a definition. We therefore took advantage of the recent effort by the Office of the National Coordinator for Health IT (ONC) to create a similar functionality-based, technology-agnostic definition of interoperability^{11,12} in order to begin to measure and track interoperability in a consistent and comparable way over time.

The definition includes 4 key domains: find, send, receive, and integrate,¹³ reflecting the fact that interoperability is comprised of multiple processes. Finding information involves the ability to query for patient data from outside institutions, and is a critical capability for unplanned care, such as emergency department visits. Sending

ABSTRACT

OBJECTIVES: To assess US hospital engagement in the 4 core domains of interoperability (find, send, receive, integrate) and whether engaging in these domains is associated with electronic availability of clinical data from outside providers.

STUDY DESIGN: Retrospective analysis of survey data.

METHODS: Analysis of the American Hospital Association (AHA) Annual Survey of Hospitals and the American Hospital Association (AHA) Annual Survey of Hospitals - IT Supplement datasets for 2014. Respondents included 3307 US hospitals to the AHA Annual Survey - IT Supplement. We created measures of hospital engagement in 4 core domains of interoperability, as well as access to electronic clinical data from outside providers. Regression analysis was to identify hospital characteristics associated with each measure.

RESULTS: Twenty-one percent of US hospitals engaged in all 4 interoperability domains, and 25% engaged in none. Hospitals engaged in all 4 domains were more likely to have a “basic” (odds ratio [OR], 3.53; $P < .01$) or “comprehensive” (OR, 5.04; $P < .01$) electronic health record (EHR) in comparison to a less than “basic” EHR, participate in a Regional Health Information Organization (OR, 4.29; $P < .01$), use a single EHR vendor (OR, 2.15; $P < .01$), and have a third-party health information exchange vendor (OR, 2.32; $P < .01$). They also differed by non-IT characteristics, such as medical home participation (OR, 1.77; $P < .01$). Hospitals that find (OR, 5.51; $P < .01$), receive (OR, 2.56; $P < .01$), or integrate (OR, 2.53; $P < .01$) information were more likely to report routine clinical information availability from outside providers.

CONCLUSIONS: The one-fifth of US hospitals engaged in key domains of interoperability were more likely to have certain information technology infrastructure and participate in delivery reform. Encouragingly, interoperability engagement was associated with routine clinical information availability. Our results point to the need for ongoing efforts to expand interoperability, with the potential benefit of better information availability for clinicians and better care.

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TAKE-AWAY POINTS

The Office of the National Coordinator for Health Information Technology (IT) has defined 4 domains of interoperability: find, send, receive, and integrate patient health information from outside sources. We evaluated the current state of US hospitals' engagement in interoperability:

- ▶ Only 21% of all US hospitals engage in all 4 domains of interoperability.
- ▶ Health IT infrastructure, such as robust electronic health record systems and health information organization participation, and delivery reform engagement are positively associated with engagement in all 4 domains.
- ▶ Three of the 4 domains—finding, receiving, and integrating—are significantly associated with provider access to patient information from outside providers.
- ▶ Hospitals that have invested in interoperability capabilities appear to have better access to patient information. However, given that less than 1 in 4 hospitals have these capabilities, additional policy interventions to encourage interoperability are needed.

and receiving can enable providers to exchange patient information during planned care transitions, such as referrals or following hospital discharge. Integrating patient information is the key capability that distinguishes interoperability from health information exchange (HIE); interoperability requires both that information is shared electronically and that no special effort on behalf of the user is needed to integrate that information into the provider's EHR.¹⁴ Taken together, these 4 domains capture the core components of interoperability required for varied use cases in which provider organizations need to share information electronically.

Using these 4 domains as a framework, we sought to capture a current picture of interoperability in US hospitals, assess how interoperability varies by hospital characteristics—including health IT infrastructure, payment reform participation, and other demographics— and examine whether interoperability is associated with electronic availability of information from outside organizations at the point of care. We used data from the 2014 American Hospital Association (AHA) Annual Survey of Hospitals – IT Supplement that included new questions on these capabilities. Our study is therefore the first to our knowledge to use this new functionality-based definition of interoperability, and offers a set of benchmark measures against which future progress can be assessed. This is critical to inform the wide array of efforts currently underway to ensure that disparate EHRs can provide clinicians access to complete patient information.

METHODS

Data and Sample

Our study relied on data from 3 sources. We used data from the 2014 AHA IT Supplement to capture hospital engagement in the 4 domains of interoperability along with other measures of hospital characteristics.¹⁵ This survey is sent annually to the CEO of every hospital in the United States, and he or she is asked to complete it or delegate completion to a knowledgeable person in the organization. The 2014

AHA IT Supplement was fielded between November 2014 and February 2015, was sent to 6377 hospitals, and received 3307 responses.

Our second source of data was the 2014 AHA Annual Survey, fielded in the same manner as the 2014 AHA IT Supplement Survey, which we used to create additional measures of hospital characteristics.¹⁵ Finally, we used Stage 2 Meaningful Use attestation data from CMS' 2015 Medicare Electronic Health Record Incentive Program Eligible Professionals Public Use File, which allowed us to measure the density of potential ambulatory partners with electronic exchange capabilities in each hos-

pital's market.¹⁶ Our primary analytic sample included all hospitals that responded to the 2014 AHA IT Supplement, for a total of 3307 hospitals. Although previous studies examining national health IT adoption and Meaningful Use engagement have typically limited the sample to nonfederal, general acute care hospitals, we decided to include federal and specialty hospitals as these hospitals deliver care that would benefit from engagement in interoperability.

Measures of Interoperability

We created 4 dichotomous measures to capture whether or not each hospital was engaged in each of the 4 interoperability domains. We also created variables to capture all the possible combinations of engagement in the 4 domains (eg, send only, send and receive only).

Finding. We defined finding data using the question, "Do providers at your hospital query electronically for patients' health information (eg, medications, outside encounters) from sources outside your organization or hospital system?" We considered hospitals that responded "yes" as finding (querying) data.

Sending and receiving. We defined sending and receiving data using questions that asked, "When a patient transitions to another care setting or organization outside your hospital system, how does your hospital routinely send and/or receive a summary of care record?" For sending, providers who responded "yes" to 1 or more of the following options—"secure messaging using EHR (via direct or other secure protocol)," "provider portal," or "via health information exchange organization or other third party"—were considered to be electronically sending data. The question offered the same options for "receive" and so we created an equivalent variable (**eAppendix Table A** [eAppendices available at www.ajmc.com]).

Integrating. We measured integrating data using responses to the question, "Does your EHR integrate any type of clinical information received electronically (not eFax) from providers or sources outside your hospital system/organization without the need for manual entry? This could be done using software to convert scanned documents into indexed, discrete data that can be

integrated into EHR.” We considered respondents who answered “yes, routinely” or “yes, but not routinely” as integrating data.

Availability of Information From Outside Organizations

We used a new question on the 2014 AHA IT Supplement to create a dichotomous measure of whether providers in the hospital routinely had clinical information electronically available from outside providers or sources when needed. The question asked, “Do providers at your hospital routinely have necessary clinical information available electronically from outside providers or sources when treating a patient who was seen by another health-care provider/setting?” We classified “yes” responses as providers had the clinical information they needed for patients who had been seen at outside providers.

Hospital Characteristics

We selected hospital characteristics, which fall into 3 categories—IT, organizational, and exchange partners—that we expected would be associated with engagement in interoperability domains. Our selection was based on prior studies examining characteristics associated with EHR adoption and participation in health information exchange (HIE) (**eAppendix Table B**).^{1,10,17}

Our IT characteristics included EHR adoption status,¹¹ participation in an RHIO,¹⁸ having a third-party HIE vendor, having their EHR vendor serve as their HIE vendor, and having primarily 1 EHR vendor. For organizational characteristics, we examined hospital size, teaching status, geographic location type, system membership, hospital ownership, specialty type, and payment reform participation.^{19,20} Finally, in order to evaluate the impact of available exchange partner density, we created 2 measures to capture potential exchange partners (**eAppendix Table C**).²¹

Analytic Models

We first calculated the proportion of hospitals engaged in every combination of the 4 interoperability domains. All measures used weights generated by an inverse probability model predicting response to the 2014 AHA IT Supplement, based on size, teaching status, system membership, region, urban/rural location, ownership, and critical access status (defined as a subset of rural hospitals identified by CMS as those that provide care services in certain rural areas, from the 2014 AHA Annual Survey). These weights both account for nonresponse bias and create nationally representative estimates.

Next, to assess the relationship between interoperability engagement and hospital characteristics, we identified the characteristics associated with hospitals that engage in all 4 domains compared with 3 or fewer. We ran a logistic regression model using engagement in all 4 interoperability domains as our dependent variable, and our hospital characteristics as explanatory variables, using the probability weights described above and clustering standard errors

by Hospital Referral Region (HRR). We ran the model twice: once with IT, organizational, and exchange partner measures, and once with only IT and organizational measures; we did this because the exchange partner measures reduced our sample size from 3307 to 2279 respondents.

Finally, we examined the predictors of information availability from outside organizations. Our explanatory variables in the logistic regression model were the 4 interoperability domain variables: find, send, receive, and integrate. We included send as a logic check, and did not expect that sending data would be significantly associated with clinical information availability. Additional explanatory variables included the hospital characteristics from the previous model. We removed the variables that we did not expect would be related to information availability: having a third-party HIE vendor, having their EHR vendor as their HIE vendor, and using primarily 1 EHR vendor; these measures are key enablers of interoperability engagement, but not likely related to clinical information availability. The model included the same weights, and was run twice, with and without exchange partner measures. Finally, to assess the potential for synergistic effects from engaging in multiple interoperability domains, we re-ran the model with all possible interaction terms between find, send, receive, and integrate.

RESULTS

Sample Characteristics

Over half of the hospitals had at least a “basic” (defined as an EHR with a set of 10 functionalities implemented in at least 1 unit of the hospital) EHR system (60%), while “comprehensive” (defined as an EHR with a larger set of functionalities implemented across all units of the hospital) EHR systems were less common (29%). Nearly half of the hospitals were participating in a RHIO (49%), and many hospitals had a third-party HIE vendor (80%). The majority of hospitals in our sample were small (53%) or medium-sized (40%); most hospitals were located in an urban setting (64%) and nearly half were privately owned, nonprofit (49%) (**eAppendix Table D**). Almost one-fifth of sample hospitals participated in an ACO (17%) and a medical home (17%), with only 8% participating in both. In HRR-level markets with at least 10 respondents, 68% of hospitals in the market, on average, engaged in sending information electronically. Similarly, the mean number of “eligible provider” exchange partners per hospital by HRR was 1.45 across all hospitals in the sample (**eAppendix Table C**).

Interoperability in US Hospitals

Twenty-one percent of US hospitals engaged in all 4 interoperability domains (**Table 1** and **eAppendix Figure**). An additional 17% of hospitals engaged in some combination of the 3 domains—the most common of which was send, receive, and integrate data (8% of

TABLE 1. US Hospitals Engaging in Interoperability by Domain^{a,b,c}

Core Domain of Interoperability	Number of Hospitals	Percentage of Hospitals
All 4 (find, send, receive, integrate)	693	21%
3 of 4	574	17%
Send, receive, and integrate	266	8%
Find, send, and receive	213	6%
Find, send, and integrate	93	3%
Find, receive, and integrate	2	0.1%
2 of 4	654	20%
Send and receive	331	10%
Send and integrate	147	5%
Find and send	110	3%
Find and integrate	47	1%
Find and receive	10	0.3%
Receive and integrate	9	0.3%
1 of 4	551	17%
Send	263	8%
Find	127	4%
Integrate	118	4%
Receive	43	1%
None	805	25%

^aN = 3277.

^bValues represent proportion of US hospitals sending, receiving, finding, and integrating patient records electronically.

^cResults are weighted so that they are nationally representative.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement.¹⁵

total respondents). Another 20% of hospitals engaged in 2 domains of interoperability, with the most common combination being send and receive (10% of total respondents). Seventeen percent of hospitals engaged in 1 of the domains of interoperability, and the most common single domain was send (8% of total respondents). The remaining one-fourth of hospitals did not engage in any of the 4 domains.

Hospital Characteristics Associated With Engagement in All 4 Interoperability Domains

Several characteristics were significantly associated with hospital engagement in all 4 domains of interoperability (Table 2). Hospitals with a basic or comprehensive EHR (odds ratio [OR], 3.53 and 5.04, respectively; $P < .01$) were more likely to be engaged in all 4 domains, as were hospitals participating in an RHIO (OR, 4.29; $P < .01$). Hospitals with a third-party HIE vendor (OR, 2.32; $P < .01$), hospitals using their EHR vendor as their HIE vendor (OR, 2.15; $P < .01$), and hospitals using only 1 EHR vendor (OR, 2.04; $P < .01$) were also more likely to be engaged in all 4 domains.

Among the organizational characteristics, medium-sized hospitals (OR, 1.51; $P < .01$) and hospitals that are part of a system (OR, 1.88; $P < .01$) were more likely to engage in all 4 interoperability

domains, as were hospitals participating in a medical home model¹⁸ (OR, 1.77; $P < .01$) or both an accountable care organization (ACO) and a medical home model (OR, 1.78; $P = .02$).

When we examined the exchange partner density variables, neither the proportion of hospitals in the HRR that electronically send information nor the number of eligible professionals in the HRR that had attested to Stage 2 Meaningful Use, were related to engagement in all 4 interoperability domains (eAppendix Table E).

Characteristics Associated With Clinical Data Availability

Just over one-third of sample hospitals reported having clinical information available from outside providers when necessary (36%) (eAppendix Table D). Find (OR, 5.51; $P < .01$), receive (OR, 2.56; $P < .01$), and integrate (OR, 2.53; $P < .01$) information were associated with the availability of information from outside providers. As expected, send was not associated with clinical information availability (OR, 0.98; $P = .92$) (Table 3).

Other statistically significant characteristics associated with electronic availability of information from outside providers included hospitals with a basic or comprehensive EHR system (OR, 1.47 and 2.02, respectively; $P < .01$), and hospitals owned by the federal government compared with privately owned nonprofit hospitals (OR, 2.29; $P = .03$). Neither exchange partner variable was related (eAppendix Table F). In our fully interacted model, hospitals that engaged in all 4 interoperability domains had significantly greater odds of electronic clinical information availability from outside sources (OR, 38.32; $P < .01$) (eAppendix Table G).

DISCUSSION

There is widespread agreement that interoperability across EHR systems is needed to ensure that providers have ready access to health information about their patients. Our results offer a baseline measure for the state of interoperability in US hospitals and suggest that continued efforts are needed both to increase interoperability and for data from outside providers to be routinely available. Key enablers of interoperability appear to center on certain health IT infrastructure and HIE services. Having a basic or comprehensive EHR ensures that there is a core set of patient information captured electronically, such as problem and medication lists, which are valuable both to share with outside providers during care transitions and update with information received from outside providers.¹ Encouragingly, all forms of technology solutions were positively associated—ranging from RHIO to third-party HIE vendors to EHR vendors providing HIE solutions. This suggests the possibility that hospitals are pursuing varied approaches to connectivity and that the policy strategy of letting the market develop different approaches to exchange may be allowing hospitals to choose the approach that works best for them.

We were somewhat surprised to find that medical home model participation was significantly associated with engaging in all 4 interoperability domains, and ACO participation alone was not. This finding could be explained by the fact that care coordination activities are core requirements of most medical home programs, and hospitals therefore have to invest in some level of sending, receiving, and integrating information. The National Committee for Quality Assurance specifically recommends that medical homes invest in interoperability and HIE capabilities for the purposes of care coordination and ensuring high-quality care.²⁰ We also found that being a member of a system was associated with engagement in interoperability. We suspect that hospitals that are part of a system are more likely to share patients with other members of the system, making interoperability more valuable, as well as have established relationships and policies with other members of the system that make exchange easier.

Many of the characteristics that we hypothesized would be related to interoperability engagement were not, including several that have historically been associated with EHR adoption. Large hospitals, teaching hospitals, and urban hospitals were not more likely to be engaged, despite being more likely to have comprehensive EHR systems.¹ This suggests that a different set of factors influence interoperability engagement compared with EHR adoption.¹¹ For example, large hospitals may have been able to leverage their greater resources in EHR adoption, but the increased complexity that comes with being a larger facility may make engaging in interoperability more difficult. Although there is a growing understanding of the barriers to interoperability,⁹ our findings suggest the need for further exploration across different hospital settings.

Our findings related to predictors of clinical information availability from outside providers also yielded interesting insights. That find and receive were both associated with clinical information availability reinforces the notion that different types of information access are needed for different clinical scenarios. Whereas finding is needed in emergency care

TABLE 2. Characteristics Associated With US Hospitals Engaging in All 4 Core Domains of Interoperability^{a,b,c}

Characteristic	Odds Ratio (95% CI)	P
Information technology		
Hospitals having less than a "basic" EHR system	Ref	
Hospitals having a "basic" EHR system	3.53 (2.40-5.18)	<.01
Hospitals having a "comprehensive" EHR system	5.04 (3.38-7.51)	<.01
Hospitals participating in a Regional Health Information Organization	4.29 (3.11-5.94)	<.01
Hospitals using their EHR vendor as their HIE vendor	2.15 (1.51-3.06)	<.01
Hospitals with a third-party HIE vendor	2.32 (1.65-3.27)	<.01
Hospitals using only one EHR vendor	2.04 (1.29-3.22)	<.01
Hospital size		
Small hospitals fewer than 100 beds	Ref	
Hospitals between 100 and 500 beds	1.51 (1.17-1.96)	<.01
Hospitals over 500 beds	1.11 (0.71-1.92)	.69
Teaching status		
Non-teaching hospitals	Ref	
Teaching hospitals	0.91 (0.67-1.81)	.56
Location		
Hospitals located in a rural setting	Ref	
Hospitals located in an urban setting	0.99 (0.74-1.33)	.96
System membership		
Hospitals not part of a healthcare system	Ref	
Hospitals part of a healthcare system	1.88 (1.39-2.54)	<.01
Hospital ownership		
Privately owned nonprofit hospitals	Ref	
Hospital owned by local (nonfederal) government	0.75 (0.53-1.06)	.11
Hospital privately owned for profit	1.51 (0.98-2.34)	.06
Hospital owned by federal government	0.45 (0.19-1.10)	.08
Hospital type		
General medical surgical hospital	Ref	
Any specialty hospital	0.82 (0.55-1.22)	.32
Payment reform participation		
Not participating in ACO or medical home	Ref	
Participation in an ACO only	1.22 (0.76-1.97)	.41
Participation in medical home only	1.77 (1.19-2.64)	<.01
Participation in both an ACO and medical home	1.78 (1.08-2.92)	.02

ACO indicates accountable care organization; EHR, electronic health record; HIE, health information exchange; Ref, reference.

^aN = 3277.

^bResults are weighted so that they are nationally representative.

^cClustered by Hospital Referral Region.

Source: Authors' Analysis of Annual AHA Survey and Annual AHA Survey – IT Supplement.¹⁵

TABLE 3. Characteristics Associated With Clinical Information Availability in US Hospitals^{a,b,c}

Characteristic	Odds Ratio (95% CI)	P
Interoperability activity domains ^d		
Find: electronically query	5.51 (4.33-7.00)	<.01
Send: electronically send data	0.98 (0.68-1.42)	.92
Receive: electronically receive data	2.56 (1.93-3.41)	<.01
Integrate: integrate electronic data into EHR without manual intervention	2.53 (1.93-3.31)	<.01
Other information technology		
Hospitals having less than a "basic" EHR system	Ref	
Hospitals having a "basic" EHR system	1.47 (1.13-1.91)	<.01
Hospitals having a "comprehensive" EHR system	2.02 (1.50-2.75)	<.01
Hospitals participating in a Regional Health Information Organization	1.24 (0.98-1.58)	.08
Hospital size		
Small hospitals fewer than 100 beds	Ref	
Hospitals between 100 and 500 beds	0.87 (0.69-1.11)	.27
Hospitals over 500 beds	1.04 (0.69-1.59)	.83
Teaching status		
Non-teaching hospitals	Ref	
Teaching hospitals	0.84 (0.64-1.10)	.21
Location		
Hospitals located in a rural setting	Ref	
Hospitals located in an urban setting	1.18 (0.91-1.52)	.20
System membership		
Hospitals not part of a healthcare system	Ref	
Hospitals part of a healthcare system	1.10 (0.86-1.41)	.42
Hospital ownership		
Privately owned nonprofit hospitals	Ref	
Hospital owned by local (nonfederal) government	0.83 (0.64-1.08)	.17
Hospital privately owned for-profit	0.72 (0.50-1.05)	.08
Hospital owned by federal government	2.33 (1.11-4.90)	.03
Hospital type		
General medical surgical hospital	Ref	
Any specialty hospital	1.42 (0.98-2.06)	.07
Payment reform participation		
Not participating in ACO or medical home	Ref	
Participation in an ACO only	0.93 (0.62-1.39)	.71
Participation in medical home only	1.02 (0.72-1.46)	.91
Participation in both an ACO and medical home	0.72 (0.43-1.21)	.21

ACO indicates accountable care organization; EHR, electronic health record; Ref, reference.

^aN = 3277.

^bResults are weighted so that they are nationally representative.

^cClustered by Hospital Referral Region.

^dFind, Send, Receive, and Integrate variables are not mutually exclusive.

Source: Authors' Analysis of Annual AHA Survey and Annual AHA Survey - IT Supplement.¹⁵

or when the provider does not know where the patient has previously received care,²² receiving data supports planned care transitions.²³ Integrating appears to offer additional value, likely by decreasing the workload for clinicians to view and incorporate information into workflow and decision making. A recent systematic review of the HIE literature found that the key barriers reported from a provider standpoint were workflow disruptions and technical trouble with the interface.²⁴ By integrating clinical information directly into hospital EHRs, clinicians are more likely to have access to outside information.^{25,26}

Limitations

Our findings should be interpreted with some key limitations in mind. First, we used self-reported survey data and were not able to verify the accuracy of responses. However, data from the AHA IT Supplement are widely used to track hospital EHR adoption and have been validated against other sources.²⁷ Our measures of engagement in the 4 interoperability domains and measure of availability of clinical information from outside providers are dichotomous, thus limiting our ability to measure the breadth of engagement and the degree to which information are available. Although survey questions related to the domains of send and receive refer specifically to summary of care records,¹¹ the questions related to the domains of find and integrate refer to any clinical patient information. Another measurement challenge is the fact that respondents could have differentially interpreted what it meant to engage in a domain "routinely."

In addition, we focused on hospital characteristics and only included 2 market-level measures related to exchange partner density. Prior work suggests that market forces play an important role in hospitals' decisions to pursue interoperability,^{10,28} and this points to the need for additional research focused on examining these dynamics. Finally, our cross-sectional data captures a recent snapshot of interoperability and, although we speculate on some potential causal relationships, we cannot empirically assess them. It is important to note

that our study reports slightly different results than previous ONC publications on US hospital interoperability engagement using the same data source.⁹ This discrepancy is due to our decision to include all hospitals in our results rather than only nonfederal, acute care hospitals. Although federal and specialty hospitals are not subject to the same policy environment as general hospitals—because the same patients may receive care at both types of hospitals—we felt it was important to include all hospitals in our measures.

Implications

Our findings have important policy implications. First, the measures of interoperability engagement that we examine in this study are part of the final set of measures that will be used to report to Congress to assess the extent to which interoperability is occurring on a wide-spread basis by 2018, as mandated by the Medicare Access and CHIP Reauthorization Act (MACRA) rule.²⁹ Our findings lend credibility to these measures, given that we found they are strongly associated with increased availability of outside information. However, given that we also found a majority of hospitals do not engage in all 4 domains, there is a need for ongoing policy efforts to increase such engagement. Efforts to enable interoperability should not solely focus on sending information during care transitions—which is heavily emphasized in current Meaningful Use criteria—but also on finding, receiving, and integrating information. MACRA takes a step in this direction by encouraging providers to not only send, but also receive and incorporate, patient care records electronically.³⁰ However, they would need to be expanded in at least 2 key ways: the MACRA rules only apply to eligible providers, not hospitals, and they set a fairly low bar with regard to integrating information. Progress in the integration domain would also likely be sped up by efforts to identify and implement the best available data standards that enable receiving and integrating data across systems. As a start, vendors representing 90% of the hospital EHR market have committed to implement “national interoperability standards and best practices”³¹ that are part of the Shared Nationwide Interoperability Roadmap.¹³

Although delivery and payment reform should also drive hospitals toward greater engagement in interoperability, our findings suggest that these forces have not yet fully matured. Specifically, while medical home model participation was associated with engaging in all 4 domains of interoperability, participation in only ACOs was not. Reform efforts could become more forceful levers if interoperability-sensitive outcome measures were developed and then tied to participation and payment.^{4,32} Regardless, as delivery and payment reform accelerate, hospitals will need cost-effective options to seamlessly exchange information. Linking interoperability to various initiatives and funding sources, such as state innovation model funding, new Health Information Technology for Economic and Clinical Health match funding for Medicaid, and Medicaid managed care contracting, could help address remaining gaps across the country with regards to interoperability engagement.³³

CONCLUSIONS

We used recent survey data from US hospitals to assess the current state of interoperability using a functionality-based definition comprised of 4 core domains. Only one-fifth of hospitals engaged in all 4 domains of interoperability; hospitals possessing key health IT capabilities were more likely to engage in all 4. Organizational characteristics associated with interoperability differed from those associated with hospital EHR adoption, suggesting a unique set of factors affecting hospital interoperability. Perhaps most importantly, engaging in finding, receiving, and integrating information was strongly associated with routine availability of necessary clinical information from outside providers. This underscores the need to speed progress toward ensuring that all hospitals engage in these core domains of interoperability. Policy interventions, including the expansion of value-based delivery reform like medical homes and new interoperability incentives contained in MACRA, may speed hospital engagement in interoperability and the improved outcomes that are expected to follow. ■

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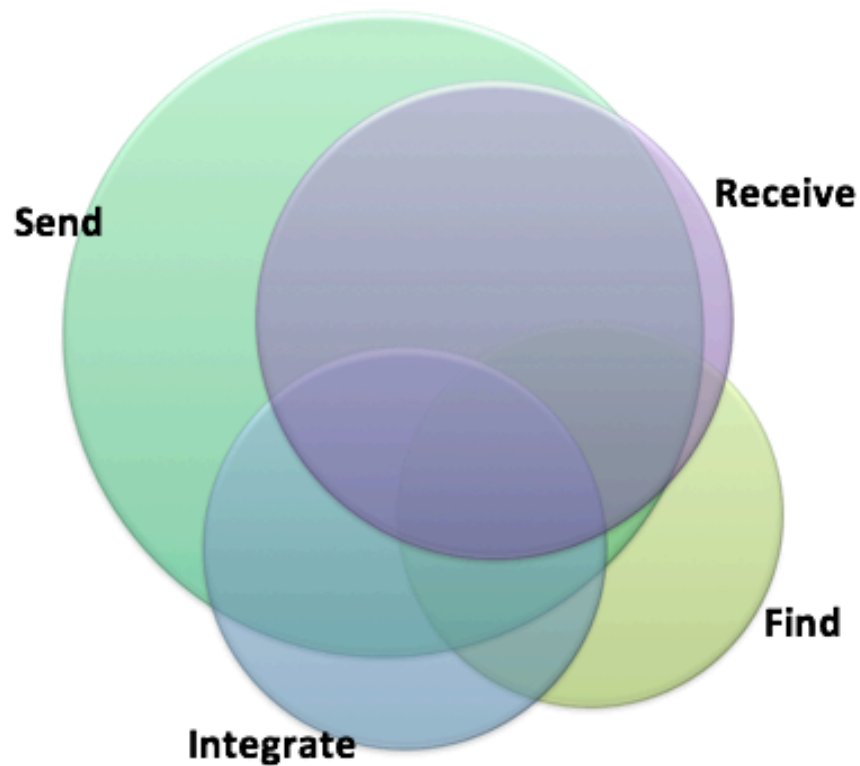
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eAppendix

eAppendix Figure. US Hospitals Engaging in Interoperability by Domain



US Hospitals Engaging in Core Domains of Interoperability (2014).

N = 3277.

Size of circles represent proportion of US hospitals sending, receiving, finding and integrating patient records electronically.

Results are weighted so that they are nationally representative.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement.¹

eAppendix Table A. Mechanisms for Sending and Receiving Data

Mechanisms for Sending / Receiving Electronic Health Data	Send (%)	Receive (%)
Secure messaging using EHR (via DIRECT or other secure protocol)	1822 (55)	1262 (39)
Provider portal (ie, post to portal or download from portal)	1088 (33)	671 (20)
Via health information exchange organization or other third party	1893 (57)	1014 (31)

N = 3277.

Results are weighted so that they are nationally representative.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement, Annual AHA survey.¹

eAppendix Table B. Measure Creation Details

Characteristic	Description
Information Technology	
Hospitals having less than a “basic” EHR system	EHRs that do not meet the standard for “basic” or “comprehensive”
Hospitals having a “basic” EHR system	EHRs that have adopted at least 10 functions, such as problem lists and medication lists, in at least one unit of the hospital. ¹¹
Hospitals having a “comprehensive” EHR system	EHRs that have adopted 24 functions across all units of the hospital. ¹¹
Hospitals participating in a Regional Health Information Organization	Hospitals that responded “Yes” to “HIE/HIO is operational in my area and we are participating and actively engaging data in at least one HIE/RHIO.”
Hospitals using their EHR vendor as their HIE vendor	Hospitals answering “Yes” to “Same system as our primary inpatient EMR (electronic medical record) system.
Hospitals with a third-party HIE vendor	Hospitals answering “Yes” to any of the specifically named third-party HIE vendors, but not to “Other”, or “Same system as our primary inpatient EMR (electronic medical record) system.
Hospitals using only one EHR vendor	Hospitals that answered “Primarily one vendor” to “On the whole, how would you describe your EMR/EHR system?”
Hospital Size	
Small hospitals fewer than 100 beds	Based on bed totals from AHA Annual Survey IT Supplement. Hospitals with fewer than 100 beds were considered “Small.”
Hospitals between 100 and 500 beds	Based on bed totals from AHA Annual Survey IT Supplement. Hospitals with between 100 and 500 beds were considered “Medium.”
Hospitals over 500 beds	Based on bed totals from AHA Annual Survey IT Supplement. Hospitals with over 500 beds were considered “Large.”
Teaching Status	
Non-teaching Hospitals	Hospitals not approved to participate in residency and/or internship training by the Accreditation Council for Graduate Medical Education, or serving as a member of the Council of Teaching Hospitals (COTH) of the Association of American Medical Colleges per AHA Annual Survey.
Teaching Hospitals	Hospitals to be approved to participate in residency and/or internship training by the Accreditation Council for Graduate Medical Education, or serving as a member of the Council of Teaching Hospitals (COTH) of the Association of American Medical Colleges per

	AHA Annual Survey.
Location	
Hospitals located in a rural setting	Hospitals designated as “Rural” or “Micropolitan” per AHA Annual Survey.
Hospitals located in an urban setting	Hospitals designated as “Division” or “Metropolitan” per AHA Annual Survey.
System Membership	
Hospitals not part of a health care system	Hospitals identified as not part of a healthcare system per AHA membership details.
Hospitals part of a health care system	Hospitals identified as part of a healthcare system per AHA membership.
Hospital Ownership	
Privately owned non-profit hospitals	Hospitals identified as nongovernment, not-for-profit hospitals per AHA membership (including church operated or other.)
Hospital owned by local (non-federal) government	Hospitals identified as government, nonfederal hospitals per AHA membership (including state, county, city, city-county, or hospital district or authority.)
Hospital privately owned for-profit	Hospitals identified as investor-owned, for-profit hospitals per AHA membership (including individual, partnership, or corporation.)
Hospital owned by federal government	Hospitals identified as government, federal hospitals per AHA membership (including Air Force, Army, Navy, Public Health Service, Veterans Affairs, Department of Justice, and Other Federal)
Hospital Type	
General medical surgical hospital	Hospitals identified as “General medical and surgical” hospitals per AHA membership.
Any specialty hospital	Hospitals identified as anything other than “General medical and surgical” hospitals per AHA membership.
Payment Reform Participation	
Not participating in ACO or Medical Home	Hospitals who responded “No” to both Accountable Care Organization and Medical Home questions below.
Participation in an Accountable Care Organization	Hospitals who responded “Yes” to “Has your hospital or health care system established an accountable care organization (ACO)?”
Participation in Medical Home only	Hospitals who responded “Yes” to “Does your hospital have an established medical home program?”
Participation in both an ACO and Medical Home	Hospitals who responded “Yes” to both Accountable Care Organization and Medical Home questions above.

Source: Description of AHA Annual Survey – IT Supplement and Annual AHA Survey¹ questions used to create key measures.

eAppendix Table C. Market Characteristic Descriptive Statistics

Market Characteristic	Mean	Standard Deviation	Min - Max
Proportion of hospitals in market that send data	0.68	0.15	0.31 – 1
Eligible providers who electronically transmit Summary of Care documents, normalized per hospital in market (rate)	1.45	1.76	0 – 13.67

Results are weighted so that they are nationally representative. The first measure is the proportion of hospitals in each HRR that engage in sending data. That proportion was then assigned to each hospital in that HRR for all HRRs with ten or more respondents in the AHA Annual Survey – IT Supplement, while hospitals in HRRs with fewer than 10 respondents were excluded from the sample in our models using this variable. The second measure was created by summing the number of eligible professionals who attested to Stage 2 Meaningful Use and did not request an exception for the electronic summary of care record measure, and dividing it by the number of hospitals within the HRR to normalize by density. This proportion was then assigned to each hospital in the HRR. First market variable describes rate of hospitals who send data in HRR, excluding any HRR with fewer than 10 hospitals reporting in the AHA Survey – IT Supplement. Second market variable describes the number of Eligible Providers who send Summary of Care data electronically, per CMS Meaningful Use Stage 2 Attestation data, normalized by number of hospitals in the HRR as provided by the Annual AHA survey.

Source: Authors’ Analysis of Annual AHA Survey – IT Supplement, Annual AHA survey, and publically available CMS Meaningful Use Stage 2 Attestation Data.^{1,2}

eAppendix Table D. Sample Descriptive Statistics

Characteristic	Number of Respondents (%)
Information Technology	
Hospitals having a “basic” EHR system	1,981 (60)
Hospitals having a “comprehensive” EHR system	966 (29)
Hospitals participating in a Regional Health Information Organization	1591 (49)
Hospitals using their EHR vendor as their HIE vendor	1290 (42)
Hospitals with a third-party HIE vendor	1338 (41)
Hospitals using only one EHR Vendor	2469 (75)
Hospital Size	
Small hospitals fewer than 100 beds	1750 (53)
Hospitals between 100 and 500 beds	1327 (40)
Hospitals over 500 beds	200 (6)
Teaching Status	
Non-teaching Hospitals	2637 (80)
Teaching Hospitals	639 (20)
Location	
Hospitals located in a rural setting	1179 (36)
Hospitals located in an urban setting	2097 (64)
System Membership	
Hospital not part of a health care system	1336 (41)
Hospital part of a health care system	1940 (59)
Hospital Ownership	
Hospital privately owned non-profit	1616 (49)
Hospital owned by local (non-federal) government	678 (21)
Hospital privately owned for-profit	842 (26)
Hospital owned by federal government	98 (3)
Hospital Type	

General medical surgical hospital	2495 (76)
Any specialty hospital	782 (24)
Payment Reform Participation	
Participation in an Accountable Care Organization	580 (17)
Participation in Medical Home	553 (17)
Participation in both an ACO and a Medical Home	274 (8)
Outcomes	
Clinical data available when necessary	1167 (36)

N = 3277.

Results are weighted so that they are nationally representative.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement, Annual AHA survey, and publically available CMS Meaningful Use Stage 2 Attestation Data.^{1,2}

eAppendix Table E. Characteristics Associated With Adoption of All Core Interoperability Capabilities: Including Market Characteristics

Characteristic	Odds Ratio (95% CI)	P-Value
Information Technology		
Hospitals having less than a “basic” EHR system	Reference	
Hospitals having a “basic” EHR system	3.96 (2.48 – 6.32)	<0.01
Hospitals having a “comprehensive” EHR system	6.15 (3.80 – 9.96)	<0.01
Hospitals participating in a Regional Health Information Organization	4.53 (3.11 – 6.60)	<0.01
Hospitals using their EHR vendor as their HIE vendor	1.97 (1.26 – 3.07)	<0.01
Hospitals with a third-party HIE vendor	2.03 (1.33 – 3.11)	<0.01
Hospitals using only one EHR vendor	1.81 (0.98 - 3.32)	0.06
Hospital Size		
Small hospitals fewer than 100 beds	Reference	
Hospitals between 100 and 500 beds	1.53 (1.10 - 2.12)	0.01
Hospitals over 500 beds	1.21 (0.66 – 2.22)	0.62
Teaching Status		
Non-teaching Hospitals	Reference	
Teaching Hospitals	0.82 (0.55 - 1.22)	0.32
Location		
Hospitals located in a rural setting	Reference	
Hospitals located in an urban setting	1.13 (0.77 - 1.65)	0.54
System Membership		
Hospital not part of a health care system	Reference	
Hospital part of a health care system	1.99 (1.36 – 2.92)	<0.01
Hospital Type		
General medical surgical hospital	Reference	
Any specialty hospital	0.86 (0.54 – 1.35)	0.51
Hospital Ownership		
Privately owned non-profit hospitals	Reference	
Hospital owned by local (non-federal) government	0.78 (0.52 - 1.17)	0.23

Hospital privately owned for-profit	1.26 (0.73 - 2.19)	0.41
Hospital owned by federal government	0.38 (0.15 - 1.00)	0.05
Payment Reform Participation		
Not participating in ACO or Medical Home	Reference	
Participation in an Accountable Care Organization only	1.19 (0.66 - 2.13)	0.56
Participation in Medical Home only	1.97 (1.16 - 3.35)	0.01
Participation in an ACO and Medical Home	1.73 (0.92 - 3.26)	0.09
Market Characteristics		
Proportion of hospitals in market that send data	2.14 (0.60 - 7.72)	0.24
Eligible providers who electronically transmit Summary of Care documents, normalized per hospital in market (rate)	1.03 (0.86 - 1.22)	0.76

Characteristics Associated with Adoption of All Core Interoperability Capabilities: Including Market Characteristics (2014)

N = 3277.

Results are weighted so that they are nationally representative. Find, Send, Receive, and Integrate variables are not mutually exclusive. Clustered by HRR. First market variable describes rate of hospitals who send data in HRR, excluding any HRR with fewer than 10 hospitals reporting in the AHA Survey – IT Supplement. Second market variable describes the number of Eligible Providers who send Summary of Care data electronically, per CMS Meaningful Use Stage 2 Attestation data, normalized by number of hospitals in the HRR as provided by the Annual AHA survey. Market variables taken from different model in order to preserve sample size for other variables.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement, Annual AHA survey, and publically available CMS Meaningful Use Stage 2 Attestation Data.^{1,2}

eAppendix Table F. Characteristics Associated With Clinical Data Availability: Including Market Characteristics

Characteristic	Odds Ratio (95% CI)	P
Electronic Capabilities		
FIND: Electronically query	5.48 (4.13 - 7.28)	<0.01
SEND: Electronically send data	1.00 (0.65 - 1.53)	0.99
RECEIVE: Electronically receive data	2.24 (1.61 - 3.11)	<0.01
INTEGRATE: Integrate electronic data into EHR without manual intervention	2.70 (1.92 - 3.80)	<0.01
Other Information Technology		
Hospitals having less than a “basic” EHR system	Reference	
Hospitals having a “basic” EHR system	1.56 (1.13 - 2.14)	0.01
Hospitals having a “comprehensive” EHR system	2.23 (1.55 - 3.20)	<0.01
Hospitals participating in a Regional Health Information Organization	1.25 (0.94 - 1.68)	0.13
Hospital Size		
Small hospitals fewer than 100 beds	Reference	
Hospitals between 100 and 500 beds	0.80 (0.59 - 1.08)	0.14
Hospitals over 500 beds	0.90 (0.55 - 1.47)	0.68
Teaching Status		
Non-teaching Hospitals	Reference	
Teaching Hospitals	0.96 (0.67 - 1.38)	0.84
Location		
Hospitals located in a rural setting	Reference	
Hospitals located in an urban setting	1.04 (0.75 - 1.45)	0.79
System Membership		
Hospital not part of a health care system	Reference	
Hospital part of a health care system	1.05 (0.78 - 1.41)	0.74
Hospital Ownership		
Privately owned non-profit hospitals	Reference	

Hospital owned by local (non-federal) government	0.86 (0.65 - 1.14)	0.29
Hospital privately owned for-profit	0.75 (0.47 - 1.21)	0.23
Hospital owned by federal government	1.72 (0.70 - 4.24)	0.24
Hospital Type		
General medical surgical hospital	Reference	
Any specialty hospital	1.27 (0.81 – 1.98)	0.29
Payment Reform Participation		
Not participating in ACO or Medical Home	Reference	
Participation in an Accountable Care Organization only	0.97 (0.59 - 1.59)	0.91
Participation in Medical Home only	0.99 (0.63 - 1.54)	0.96
Participation in an ACO and Medical Home	0.68 (0.35 - 1.35)	0.27
Market Characteristics		
Proportion of hospitals in market that send data	1.63 (0.63 - 4.21)	0.32
Eligible providers who electronically transmit Summary of Care documents, normalized per hospital in market (rate)	1.08 (0.99 - 1.17)	0.07

Characteristics Associated with Clinical Data Availability in US Hospitals: Including Market Characteristics (2014)

N = 3277.

Results are weighted so that they are nationally representative. Clustered by HRR. First market variable describes rate of hospitals who send data in HRR, excluding any HRR with fewer than 10 hospitals reporting in the AHA Survey – IT Supplement. Second market variable describes the number of Eligible Providers who send Summary of Care data electronically, per CMS Meaningful Use Stage 2 Attestation data, normalized by number of hospitals in the HRR as provided by the Annual AHA survey. Market variables taken from different model in order to preserve sample size for other variables.

Source: Authors' Analysis of Annual AHA Survey – IT Supplement, Annual AHA survey, and publically available CMS Meaningful Use Stage 2 Attestation Data.^{1,2}

eAppendix Table G. Characteristics Associated With Clinical Data Availability in US Hospitals: Fully Interacted Model

Characteristic	Odds Ratio (95% CI)	P-Value
Interoperability Activity		
FIND Only: Electronically query	3.05 (1.69 – 5.47)	<0.01
SEND Only: Electronically send data	1.34 (0.72 – 2.51)	0.36
RECEIVE Only: Electronically receive data	4.97 (2.06 – 11.98)	<0.01
INTEGRATE Only: Integrate electronic data into EHR without manual intervention	2.06 (1.03 – 4.15)	0.04
Receive & Integrate Only:	2.88 (0.53 – 15.65)	0.22
Find & Receive Only:	41.20 (9.56 – 177.49)	<0.01
Find & Integrate Only:	15.16 (7.37 – 31.15)	<0.01
Find & Send Only:	6.39 (3.62 – 11.26)	<0.01
Send & Integrate Only:	1.73 (0.88 – 3.36)	0.07
Send & Receive Only:	2.07 (1.26 – 3.39)	0.01
Find, Receive, & Integrate Only:	15.20 (1.07 – 216.08)	0.04
Find, Send, & Integrate Only:	9.59 (4.67 – 19.63)	<0.01
Find, Send, & Receive Only:	9.87 (5.84 – 16.68)	<0.01
Send, Receive, & Integrate Only:	4.86 (2.89 – 8.16)	<0.01
All Four Domains of Interoperability Only:	38.32 (22.39 – 65.59)	<0.01
Other Information Technology		
Hospitals having less than a “basic” EHR system	Reference	
Hospitals having a “basic” EHR system	1.49 (1.14 – 1.94)	<0.01
Hospitals having a “comprehensive” EHR system	2.10 (1.55 – 2.84)	<0.01
Hospitals participating in a Regional Health Information Organization	1.22 (0.96 – 1.54)	0.10
Hospital Size		
Small hospitals fewer than 100 beds	Reference	
Hospitals between 100 and 500 beds	0.86 (0.67 – 1.10)	0.11
Hospitals over 500 beds	1.03 (0.68 – 1.57)	0.90

Teaching Status		
Non-teaching Hospitals	Reference	
Teaching Hospitals	0.87 (0.66 – 1.14)	0.31
Location		
Hospitals located in a rural setting	Reference	
Hospitals located in an urban setting	1.17 (0.91 – 1.51)	0.23
System Membership		
Hospital not part of a health care system	Reference	
Hospital part of a health care system	1.09 (0.85 – 1.39)	0.48
Hospital Ownership		
Privately owned non-profit hospitals	Reference	
Hospital owned by local (non-federal) government	0.83 (0.63 – 1.08)	0.16
Hospital privately owned for-profit	0.68 (0.47 – 0.99)	0.04
Hospital owned by federal government	2.33 (1.13 – 4.79)	0.02
Hospital Type		
General medical surgical hospital	Reference	
Any specialty hospital	1.37 (0.93 – 2.01)	0.11
Payment Reform Participation		
Not participating in ACO or Medical Home	Reference	
Participation in an Accountable Care Organization only	0.92 (0.62 – 1.37)	0.70
Participation in Medical Home only	1.01 (0.70 – 1.45)	0.95
Participation in an ACO and Medical Home	0.68 (0.39 – 1.17)	0.16

N = 3277.

Results are weighted so that they are nationally representative. Model is a fully interacted version of Table 3, where all possible combinations of Find/Send/Receive/Integrate are represented and mutually exclusive. Clustered by HRR.

Source: Authors' Analysis of Annual AHA Survey and Annual AHA Survey – IT Supplement.¹

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