

Mind the Gap: The Potential of Alternative Health Information Exchange

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Open and accessible approaches to health information exchange (HIE) have been pursued for nearly 3 decades to address information silos that hamper effective coordination and transitions of care.¹⁻⁴ HIE has been shown to make information more available and accessible across provider organizations, resulting in reduced redundant testing, increased identification of medication errors, and reduced discrepancies in diagnoses, among other benefits.^{5,6} State, regional, and even national HIE infrastructures have had public political and financial support but have struggled to grow rapidly and function independently and sustainably.^{4,7-11} Because of this, alternative proprietary approaches to exchanging information have emerged in the market.^{12,13} These approaches are fundamentally different from open HIE networks because they are designed to support HIE within a specific group of providers.¹⁴ Enterprise HIE facilitates information exchange within an integrated delivery system or set of close partners.^{12,15} Similarly, electronic health record (EHR) vendor-mediated HIE, such as Epic's Care Everywhere network, is aimed at facilitating exchange among providers using the same EHR.^{16,17} Most recently, cooperative engagement in HIE networks, such as the CommonWell Health Alliance and Carequality, has promised to connect providers using any of several vendors that participate in the alliances.¹⁸⁻²⁰ These vendor networks emerged to offer solutions to common HIE issues around data governance, data standards, common contracting, and transaction credentialing.^{21,22}

These proprietary approaches are supported by more obvious business cases than are open HIEs. Enterprise HIE can help integrated health systems increase capacity for continuity and care coordination within organizations, mitigating the risk of organizations losing patients who might otherwise opt for treatment outside the system.²³⁻²⁶ For vendors, a developed intravendor HIE network may be a selling point for new customers, especially when those potential customers' key partners already use the EHR. Similarly, vendor participation in alliances can increase their appeal relative to those vendors that do not or cannot join the alliance. Although these approaches appear to be becoming more widely used, there is concern that their growth will exclude certain providers and

ABSTRACT

OBJECTIVES: To determine the proportion of patient transitions that could be connected through 3 proprietary alternatives to open, community-based health information exchange (HIE): HIE between physicians who are part of the same integrated system, use the same electronic health record (EHR), or use an EHR that participates in an EHR vendor alliance.

STUDY DESIGN: Cross-sectional analysis of Medicare patient transitions and physician EHR adoption and organizational affiliation from SK&A.

METHODS: We characterized the percentage of transitions that could be covered by each HIE approach and the degree of redundancy. We then assessed whether coverage opportunities differed by provider type and used multivariate linear regression to estimate the association between physician characteristics and proportion of transitions uncovered by any proprietary approach (ie, requiring an open HIE approach).

RESULTS: Given current EHR adoption and organizational affiliations, 33% of transitions could be covered by proprietary HIE. For the average physician, open methods of HIE would still be needed for 45% of patients treated by other physicians. Physicians who did not use a market-leading EHR, were not members of a large integrated system, and shared patients with a broader network of physicians have the greatest need for open HIE.

CONCLUSIONS: Proprietary approaches to HIE do not eliminate the need for open HIE and may further disadvantage providers in small healthcare organizations using less common EHRs. Ongoing support and innovative value creation within open HIE will likely remain necessary to support HIE by independent physicians. Public efforts to promote interoperability should seek to integrate proprietary models with open HIE.

Am J Manag Care. 2019;25(1):32-38

that care will continue to be fragmented so long as exchange is limited by EHR vendor or organizational affiliation.^{27,28}

Our objectives in this work are to measure the extent to which these proprietary HIE approaches can meet patient and provider needs for information exchange and to determine who is best served by these proprietary forms of HIE and which providers (and patients) are left behind. By doing so, we intend to estimate the continued value in pursuing open HIE as proprietary approaches become more widely available. One intuitive way to capture the relative value of different HIE approaches is to consider the proportion of patient transitions nationwide that these proprietary HIE approaches could potentially cover independently and in combination. To do so, we combined national physician survey data, from which we derived potential to engage in enterprise or vendor-based EHR solutions, with a comprehensive provider-to-provider database of shared Medicare patients. We then addressed 3 important research questions. First, what proportion of patient transitions occur between providers who could be connected by enterprise HIE, vendor-mediated HIE, and/or vendor alliance HIE? Second, does the potential for connectivity through these mechanisms differ across physician types (primary care vs specialty or surgical providers)? And finally, what organizational characteristics of physicians' practice locations are associated with being "left out" by proprietary HIE and therefore likely to remain most reliant on open HIE?

METHODS

Data

Our primary data sets were the 2017 SK&A Physician Survey and the 2016 CareSet Labs DocGraph Hop Teaming Dataset. The SK&A Physician Survey is a nationwide survey of office-based physicians that contains information on provider and organizational characteristics. The DocGraph Hop Teaming Dataset is a relational data set that captures the "sharing" of patients, in which each observation represents a pair of healthcare providers and the number of fee-for-service (FFS) Medicare patients for whom both providers in the pair appear on claims using a transaction-based approach. Pairs of providers that shared fewer than 11 patients are censored from these data following Medicare minimum cell size rules for publicly available data. This results in an inclusive measure of patient transitions defined by the number of times that patients switch providers, which reflects both intentional referrals and happenstance. Therefore, the volume of transitions provides a broad sense of the need for information exchange to support coordinated care.

In combination, these data sets allowed us to develop a large national sample of physicians, the other physicians they share patients with, and their organizational and EHR characteristics.

TAKEAWAY POINTS

- ▶ Forms of health information exchange (HIE) that restrict participation based on organizational affiliation and/or electronic health record vendor could cover up to one-third of all patient transitions that occur annually, based on descriptive national provider data.
- ▶ These approaches are redundant with each other in terms of network coverage.
- ▶ These approaches would disproportionately benefit physicians in large, integrated provider organizations with dominant vendor systems.
- ▶ A significant need for open methods of HIE remains; even with consolidating provider referral patterns, the majority of an average physician's patients would not be covered by any of these potential proprietary coverage options.

Our population of interest was all office-based physicians in the United States who treated FFS Medicare patients in 2016.

Dependent Variables: Potential HIE Connectivity

We calculated the number of transitions between physicians using a 2-step process. First, we collapsed the data so that each observation represents the total volume of patients shared between a pair of physicians (ie, is undirected), then attributed half of the total volume to each of the 2 physicians in that dyad. Second, we summed the attributed number of transitions for each physician across all pairs in the data set in which that physician is listed to calculate the total transitions per physician.

We then created 4 continuous dependent variables that capture the proportion of patients shared by each physician who can be covered by any of 4 potential connectivity options. The first 3, which are not mutually exclusive, include (1) patients shared with physicians who belonged to the same horizontally (ie, multiphysician group practice) or vertically (ie, hospital-physician integrated system) integrated provider system (potential "enterprise HIE"), (2) patients shared with physicians who used the same EHR vendor (potential "EHR vendor-mediated HIE"), and/or (3) patients shared with physicians who used an EHR vendor that participated in an alliance (potential "vendor alliance HIE"). We identified EHR vendors participating in vendor alliances by visiting each alliance's website, where participating organizations are listed.^{18,19} We then created a fourth continuous outcome, "open HIE needed," which included patients for whom none of the other forms of HIE could cover their transition. We also coded a fifth scenario in which HIE was not possible because 1 or both physicians had no EHR.

Independent Variables

Physician characteristics. We measured 4 categorical variables from the SK&A data that were likely associated with patient referral patterns and, ultimately, the value of enterprise HIE or other vendor-based proprietary solutions. These variables included (1) physician specialty (primary care, ancillary [eg, radiologists and pathologists], specialist, surgeon, and other); (2) physician practice size (solo, 2-5, 6-9, 10-19, 20-49, ≥ 50); (3) size of the multipractice physician group or hospital-physician integrated system to which a provider belongs, which we defined by first identifying

independent physicians and then dividing systems into 5 equally sized categorical quantiles by physician membership (very small system [1-20 physicians], small [21-140], medium [141-427], large [433-973], and very large [987-8743]); and (4) EHR vendor (designation of specific vendor if the vendor was 1 of the 7 with the highest market share, as well as binary indicators for any other vendor indicated or no vendor indicated).

Transition characteristics. Using the patient transition data, we created 3 categorical measures to capture the structure of the physician's network, which may relate to the value of each HIE approach. We first measured the number of other physicians with whom they transitioned patients (divided into categories by tertile: low [1-29 physicians], medium [30-107], and high [108-11,793]), as well as the percentage of their transitions that occurred with their 10 most frequent transition partners (also divided into categories by tertile: low [2.5%-28.3167% of transitions], medium [28.3169%-58.1839%], and high [58.1843%-100%]). Finally, we created a continuous variable representing the proportion of patient transitions each physician had with physicians of different specialty types (primary care, specialist, surgeon, and ancillary).

Analytic Plan

We initially calculated descriptive statistics of included physicians. Then, to address our first research question regarding opportunity for network coverage by proprietary forms of HIE, we created an Euler diagram of the percentage of all transitions potentially covered by each form of HIE. Euler diagrams allow for the visual representation of the proportion of patient transitions that could uniquely be covered by each HIE method and capture the extent of overlap (eg, redundancy in coverage of patient transitions by HIE methods). We also examined the differential potential coverage and overlap from these HIE approaches based on key organizational characteristics. We generated separate Euler diagrams for 4 subgroups of physicians: (1) those in an integrated care system with 1 of the 7 most common EHRs (by market share), (2) those in an integrated system with an EHR not in the top 7, (3) those in an independent practice with an EHR in the top 7, and (4) those in an independent practice with an EHR not in the top 7. We selected these 2 distinguishing characteristics because they most directly relate to the availability of proprietary HIE.

To address the second research question about differential coverage by specialty type, we conducted bivariate analyses to determine whether each HIE approach varies in its potential to meet the needs of different types of providers. To do this, we first calculated the number of transitions involving each type of provider (primary care, specialist, surgeon, ancillary provider) as a percentage of total transitions in the data set. For each provider type, we then compared whether the percentage of transitions containing that provider type differed across the 5 possible scenarios and tested the statistical significance of these differences using χ^2 tests.

We used a multivariate ordinary least squares regression model with standard errors clustered by practice to address our final

research question regarding which physicians have the highest need for open HIE. To do so, we estimated the proportion of each physician's patient transitions for which open HIE would still be needed even if the proprietary forms of HIE potentially available to that provider (based on organizational and EHR characteristics) were in use. Covariates included physician specialty, the proportion of patient transitions each physician had with different physician specialties, size of integrated organization, practice size, vendor, number of exchange partners, and concentration of exchange partners. All statistical analyses were performed in Stata MP 15 (Stata Corp; College Station, Texas).

RESULTS

Our sample includes 398,485 physicians who shared at least 11 Medicare patients with another physician in 2016. The sample included physicians from 2994 counties in all 50 states and the District of Columbia; see [eAppendix Table 1](#) (eAppendix available at [ajmc.com](#)) for descriptive characteristics of the sample. There were more than 1 billion Medicare patient transitions among physicians in the sample in 2016.

Summing all coverage offered by proprietary HIE (both exclusive coverage and areas of overlap), 33% of a provider's patient transitions, on average, could be covered by a combination of the 3 possible restricted HIE mechanisms ([Figure 1](#)). Internal transitions within an integrated organization, potentially covered by enterprise HIE, accounted for 22.5% of total patient transitions. Of these transitions, 9.5% were between physicians using the same EHR (indicating potential for vendor-mediated HIE) or between physicians who used an EHR connected through an alliance. The only form of proprietary HIE available to the remaining 13% of internal transitions was enterprise HIE.

EHR vendor-mediated HIE could potentially cover up to 15.6% of total transitions. However, less than one-third of these (4.5% of total transitions) would be uniquely covered through this potential mechanism. Similarly, vendor alliances could cover 12.3% of total transitions, but less than one-third (3.6% of total transitions) are reachable only through this approach. After accounting for each of these forms of HIE, and the 21.6% of transitions that occurred between pairs of physicians in which at least 1 physician did not have an EHR, open HIE remains as the only potential mechanism to cover the remaining 45.4% of all patient transitions.

The potential for proprietary HIE solutions (enterprise, vendor-mediated, or vendor alliance HIE) to cover patient transitions differed notably by physician EHR use and membership in an integrated system ([Figure 2](#)). For the average physician using 1 of the 7 most commonly adopted EHR vendors and in an integrated system, these 3 forms of HIE could cover more than half of all transitions (52.6%). More than half of these covered transitions (27.6% of total transitions) could be covered by more than 1 form of HIE. In contrast, the potential value of these HIE tools is less obvious for physicians who neither were integrated nor used one

of the largest vendors. Physicians in integrated systems with a less common EHR could have covered 41% of transitions through proprietary forms of HIE. Independent physicians would rely only on the 2 vendor-based solutions, potentially covering 24.9% of transitions for users of the most common EHRs and only 10.3% for users of less common EHR vendors.

When we examined potential coverage from proprietary HIE mechanisms based on the type of provider included in the transition, we found limited differences by provider type (eAppendix Table 2). For instance, whereas 70.1% of transitions involved medical specialists, a larger proportion of transitions (75.2%) potentially covered by vendor alliance included specialists. Across all provider types, the proportion of transitions where open HIE was needed paralleled the proportion of transitions involving that type (for instance, 30.5% of all transitions involved primary care providers and 29.9% of open HIE transitions involved primary care providers).

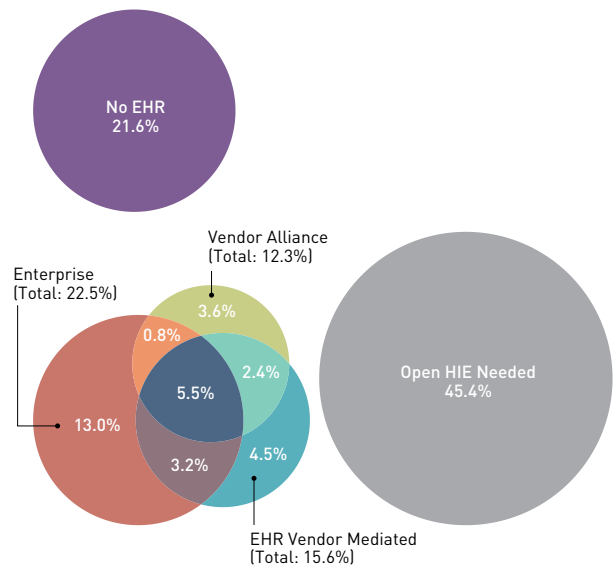
In multivariate regression analysis (Table), physician membership in a very large integrated system was associated with a decrease of 34.5 percentage points in the transitions for which open HIE was needed, relative to independent physicians. Physicians had reduced need for open HIE (ie, were better served by proprietary HIE mechanisms) when they used Epic or Cerner as their EHR vendor (decrease in need for open HIE of 14.5 and 13.5 percentage points, respectively, relative to use of a vendor other than the top 7), had few exchange partners (decreased need of 3.1 percentage points, relative to many), and concentrated partner relationships (decreased need of 5.0 percentage points, relative to dispersed). Physicians in large practices also had decreased need for open HIE relative to solo physicians, by 9.4 percentage points. All reported results were significant at $P \leq .001$, and the regression model performed well in regression diagnostics (see eAppendix Figure).

DISCUSSION

Given the EHR vendor choices and organizational membership of physicians in this large national sample, proprietary forms of HIE had the potential to cover up to one-third of all patient transitions. Of the 3 approaches to HIE, enterprise HIE within integrated care systems had the potential to cover the largest percentage of patient transitions (23%) if fully implemented. Vendor-mediated HIE also had the potential to connect almost 10% of transitions; however, a large portion of this connectivity would also be covered by enterprise HIE. Despite enthusiasm surrounding new alliance-based HIE, we found that the alliance-based approach may offer limited value beyond these 2 alternatives. However, the extent to which these HIE approaches covered a given physician's transitions differed substantially based on the physician's choice of EHR vendor and organizational membership, with large organizations that have invested in the most prominent EHR vendors receiving the most coverage from these proprietary HIE approaches.

Despite overlap, these 3 HIE approaches could offer substantial increases in the overall level of HIE—for many providers, far greater

FIGURE 1. Euler Diagram of Average Percentage of Patient Transitions Potentially Covered by 4 Forms of HIE*

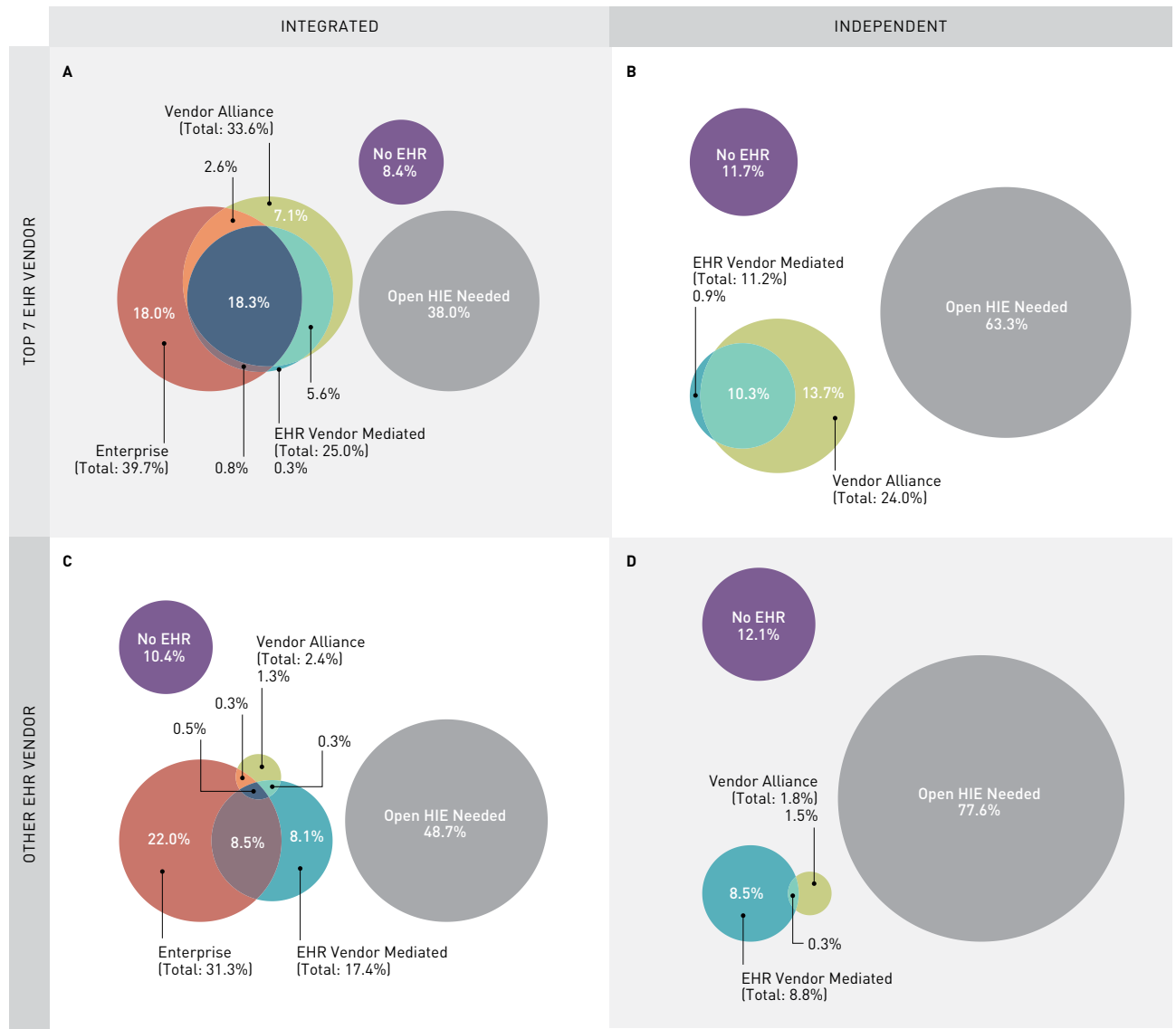


EHR indicates electronic health record; HIE, health information exchange.

*N = 398,485 physicians in SK&A survey with at least 11 unique Medicare patient transitions in 2016 who described their EHR use (including no EHR) in the 2017 SK&A survey. Enterprise HIE is defined as transitions that occur between physicians belonging to the same practice or horizontally or vertically integrated organization in the SK&A survey. EHR vendor-mediated HIE is defined as transitions that occur between physicians who use the same EHR in the SK&A data. Vendor alliance HIE is defined as transitions that occur between physicians who both use an EHR that is a partner in CommonWell or Carequality. Open HIE needed is defined as transitions that occur between physicians who both use an EHR, but do not use the same EHR or an EHR that participates in the alliances and are not members of the same organization. No EHR is defined as transitions in which at least 1 physician reported not using an EHR in SK&A data. Of the 21.6% of patient transitions that occur with a physician who does not use an EHR, 3.6 percentage points occur within the same organization.

connectivity than required by Meaningful Use criteria established for information sharing under the federal EHR incentive programs, under which attesting physicians only need to send a summary of care record for 10% of patients. Further, these approaches, led by technology companies and invested provider organizations, may offer greater usability that motivates physicians to use systems when available. However, our results suggest significant inequality with which different providers could benefit from these proprietary alternatives. Open HIE may offer lower value to physicians in large organizations with advanced EHR systems, who stand to benefit the most from investment in enterprise HIE. This corroborates recent studies' findings that large systems are less likely to engage in cross-system HIE than are small systems, and that hospital systems' investments in intersystem HIE are lower when they invest in intrasystem HIE.^{25,27} These value dynamics could incentivize leading healthcare organizations to reduce their commitment and resources to open HIE approaches like community HIEs, the Direct Trust, and Nationwide Health Information Network.²⁹⁻³¹ To the extent

FIGURE 2. Euler Diagrams of Average Percentage of Patient Transitions Potentially Covered by 4 Forms of HIE, by Physician Integration and EHR Adoption Status^a



EHR indicates electronic health record; HIE, health information exchange.

^aN = 115,889 integrated physicians using a top 7 vendor; 23,417 independent physicians using a top 7 vendor; 140,720 integrated physicians using another EHR; and 69,114 independent physicians using another EHR. Included physicians must be in 2017 SK&A survey with at least 11 unique Medicare patient transitions in 2016 who reported using an EHR in 2017 SK&A survey. Enterprise HIE is defined as transitions that occur between physicians who reported belonging to the same practice or horizontally or vertically integrated organization in the SK&A survey. EHR vendor-mediated HIE is defined as transitions that occur between physicians who use the same EHR in the SK&A data. Vendor alliance HIE is defined as transitions that occur between physicians who both use an EHR that is a partner in CommonWell or Carequality. Open HIE needed is defined as transitions that occur between physicians who both use an EHR, but do not use the same EHR or an EHR that participates in the alliances and are not members of the same organization. No EHR is defined as transitions in which at least 1 physician reported not using an EHR in SK&A data. For the top 7/integrated subgroup, on average, 2.5 percentage points of the 8.4% of patient transitions that occur with a physician who does not use an EHR (the "No EHR" circle) occurred within organizations (ie, would be classified as "Enterprise HIE" if the physician used an EHR). This represents 2.6 percentage points of 10.4% in the other EHR vendor/integrated physician group.

that broad community support for open HIE falters, independent physicians and less-resourced providers are most likely to be left out of proprietary sharing networks; this may further exacerbate disparities in quality of care for patients served by these providers.

Importantly, our estimates are based on the arrangement of organizational membership and EHR adoption in 2017. Three ongoing trends may change the value proposition of proprietary HIE: provider organization market consolidation, increasing control of the EHR

market by a few vendors, and broader participation in multivendor alliances. Intentional marketing of proprietary HIE assets may be used to accelerate these trends and create a self-fulfilling cycle of value generation. Relative to open HIE approaches, however, this still maintains siloed environments that limit patients' freedom as consumers. If information moves among only a specific subset of providers, patients may feel limited to choosing among that subset.^{26,32}

In light of these trends, our findings support targeted policy to maintain and advance open HIE infrastructure and engagement, especially among independent and small integrated systems. If open HIE attains sufficient participation from independent physicians, larger organizations may in turn be motivated to participate so that they are positioned as a referral destination for independent physicians and groups. The success of the Regional Extension Center (REC) program in increasing EHR engagement among independent and rural physicians provides one potential model for how public policy can effectively target and provide information technology (IT) assistance to physicians practicing outside of large integrated health systems.^{33,34} REC-like entities could coordinate this sizable population of unconnected providers and facilitate collaboration between providers and regional health information organizations or identify proprietary HIEs that could be approached about participation. Entities contracted to provide support to practices engaged in Medicare's Merit-based Incentive Payment System through the Small, Underserved, and Rural Support initiative are particularly well positioned to serve in this capacity, as participating practices need information exchange capability to perform successfully under value-based payment models. Outside of government support, those involved in governance of active open HIE initiatives also need to think creatively about value creation and financial sustainability. For instance, some state-level HIEs have opted to participate in growing multivendor alliances, which may offer a path to broader connectivity and operational efficiency. In addition, one important and still underused pathway toward financial sustainability is involvement of payers, which can offer unique value to open HIE (beyond just broader patient coverage), such as claims data and advanced analytics that single organizations cannot get with their enterprise HIE solutions.¹¹

Limitations

Our study is subject to a number of important limitations. Our study focused on the overall number of patient transitions between providers; we are not able to distinguish between transitions where information exchange would impact patient care and those where it might be unnecessary. However, we have no reason to suspect that the proportion of transitions where information sharing would be valuable would systematically vary by HIE approach, thus minimizing potential for biased or misleading results. We also do not know whether HIE-mediated information sharing is actually occurring in situations in places where we designate that it could potentially occur (ie, 2 providers are in the same system or share the same EHR). Therefore, our findings reflect the upper limits of the impact of

TABLE. Regression Model Predicting Percentage of Transitions in Which Open HIE Is Needed, by Physician Status (N = 398,485)

Variables	Percent of Transitions	SE ^a
Specialty (omitted: primary care)		
Ancillary	0.56	0.30
Specialist	-0.95*	0.21
Other	2.60*	0.28
Surgeon	-1.24*	0.24
Proportion of transitions with:		
Ancillary physicians ^b	7.26*	0.62
Primary care physicians	-0.85	0.68
Medical specialists	-9.59*	0.98
Surgeons	-2.28	1.04
Practice size (omitted: solo)		
2-5	-0.67*	0.14
6-9	-3.03*	0.23
10-19	-5.81*	0.28
20-50	-5.57*	0.46
≥50	-9.35*	1.43
Integrated system size (omitted: independent)		
Very small	-3.40*	0.22
Small	-13.88*	0.29
Medium	-24.70*	0.31
Large	-30.94*	0.34
Very large	-34.46*	0.40
Number of transition partners (omitted: high)		
Low	-3.13*	0.34
Medium	-2.78*	0.19
Exchange partner concentration (omitted: low)		
Medium	-2.68*	0.18
High	-4.96*	0.32
Vendor (omitted: not top 7 vendor)		
GE Healthcare	-7.51*	0.54
Athenahealth	-9.01*	0.50
Epic	-14.54*	0.36
Allscripts	-2.2*	0.40
eClinicalWorks	-6.59*	0.31
Cerner	-13.50*	0.59
NextGen Healthcare	9.98*	0.44
Has EHR, no vendor specified	11.01*	0.52
No EHR	-59.94*	0.28
Constant	76.59*	0.64

EHR indicates electronic health record; HIE, health information exchange; SE, standard error.

*P < .001.

^aAll SEs are clustered by physician practice.

^bAncillary physicians include radiologists, pathologists, and others.

each approach given current organizational membership and EHR adoption. Further, our estimates are dependent on EHR choice and integration status in 2017; their potential could change as physicians adopt different EHRs or join integrated organizations. Similarly, if new EHR vendors join the growing alliances, their potential coverage could increase. We also chose to retain ancillary providers in our measure of transitions, although, to some extent, a patient is not transitioned to the care of a radiologist or pathologist. Nevertheless, electronically supported communication among these providers could offer value in the timeliness and clarity of reports. Finally, we acknowledge that vendor alliance-based HIE is the most dynamic in terms of participation and breadth of network connectivity. Our measure of coverage for these alliances is based on EHR vendor participation; however, as these approaches have grown, they have increasingly included other healthcare organizations, technology companies, and state-level HIEs. Thus, our estimates are likely to represent a lower bound on the total value of alliance-based HIE.

CONCLUSIONS

Growing proprietary approaches to HIE have a substantial but ultimately limited potential to facilitate information exchange as patients move between providers, and these approaches are most useful to large providers using dominant EHR vendors. This dynamic indicates potential challenges for policy makers and providers. As policy makers focus on developing approaches to encourage free information exchange, their strategy should work to limit barriers among the 3 proprietary approaches described here and open HIE infrastructure. Moreover, policy can support innovation and sharing of best practices among community-based health information organizations to encourage broader participation and financial sustainability of open HIE. Providers need to strategically consider how their technology portfolio facilitates exchange with key care partners, keeping in mind that referral patterns and IT use are remarkably disparate despite trends of consolidation and integration. The ultimate goal of comprehensive network coverage still requires active engagement in nonproprietary approaches to information sharing. ■

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Source of Funding: None.

Author Disclosures: The authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (JE, DAC); acquisition of data (JE); analysis and interpretation of data (JE); drafting of the manuscript (JE, DAC); critical revision of the manuscript for important intellectual content (JE, DAC); statistical analysis (JE); administrative, technical, or logistic support (JE); and supervision (JE).

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eAppendix Table 1. Description of Sample

VARIABLES	N	(%)
Specialty		
Primary Care	117,752	29.6
Ancillary	42,943	10.8
Specialist	161,146	40.4
Other	13,526	3.4
Surgeon	63,118	15.8
Practice Size		
Solo	69,787	17.5
2-5	140,577	35.3
6-9	67,159	16.9
10-19	61,769	15.5
20-50	42,306	10.6
50+	16,887	4.2
Integrated System Size		
Independent	115,060	28.9
Very Small	56,978	14.3
Small	56,609	14.2
Medium	56,605	14.2
Large	57,236	14.4
Very Large	55,997	14.1
Vendor		
Not Top 7	259,179	65.0
NextGen	13,748	3.5
GE	10,811	2.7
Athena	8,322	2.1
Epic	51,169	12.8
Allscripts	21,824	5.5
eClinical	13,300	3.3
Cerner	13,300	3.3
Has EHR, no vendor specified	25,257	6.6
No EMR	49,345	12.4
	Mean	Standard Deviation
Concentration		
Low	0.20	0.05
Medium	0.40	0.08
High	0.87	0.15
Number of Partners		
Low	12.3	8.5

Medium	62.8	22.2
High	264.4	204.3
Proportion of Transitions with Primary Care	0.13	0.15
Proportion of Transitions with Medical Specialist	0.19	0.12
Proportion of Transitions with Surgeons	0.06	0.09
Proportion of Transitions with Ancillary Providers	0.41	0.24

eAppendix Table 2. HIE Coverage by Specialty of Sending and Receiving Physician

	Total	Enterprise Only	Vendor Mediated Only	Vendor Alliance Only	More than One HIE	Open HIE Needed
No. of transitions	1,048,647,680	119,707,232	48,150,152	40,404,564	104,327,840	526,705,216
% of all transitions	--	11.4%	4.6%	3.9%	9.9%	50.2%
Transitions Involving a:						
Primary Care	320,032,096 (30.5%)	35,485,772 (29.6%)	14,820,174 (30.8%)	14,098,242 (34.9%)	31,774,380 (30.5%)	157,691,760 (29.9%)
Specialist	734,778,112 (70.1%)	85,796,584 (71.7%)	32,527,954 (67.6%)	30,372,794 (75.2%)	76,324,864 (73.2%)	366,369,952 (69.6%)
Surgeon	150,054,064 (14.3%)	16,273,379 (13.6%)	6,733,893 (14.0%)	6,410,949 (15.9%)	14,530,891 (13.9%)	74,273,664 (14.1%)
Ancillary Provider	557,062,464 (53.1%)	59,998,400 (50.1%)	28,208,248 (58.6%)	17,577,668 (43.5%)	45,169,588 (43.3%)	294,211,456 (55.9%)

Examination of our results did not reveal worrisome over-inflation of variance (Mean VIF=2.11; maximum VIF was 7.86), demonstrated normally distributed residuals (see figure below), and the link test revealed that squared predictions contributed very little explanatory power to the model (R-squared increased from 0.5057 to 0.5197), supporting our specification.

eAppendix Figure. P-P Plot Comparing Residuals to Normal Distribution

