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The benefits of health information exchange platforms: Measuring the returns on a half a billion dollar investment[1]

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INTRODUCTION

The United States spends 17.4 percent of its GDP on health care, more than any other country in the world. Despite this $2.9 trillion expenditure, the quality and efficiency of the U.S. health care system ranks last when compared to Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom (Davis et al. 2014). As a result, a concerted national effort to reform health care using information technology (IT) with a focus on reducing costs and increasing quality of service is well under way. Electronic exchange of medical data is one of many different potential IT solutions for improving efficiency in the health care system; it facilitates the timely access to patients' medical records, which is crucial for physicians to make better decisions and avoid many redundant and often harmful medical procedures. Fewer redundancies and better medical decisions will naturally lead to much needed savings in the health care system.

Health information can be exchanged through regional health information organizations (RHIOs)[2]. A RHIO is a multi-sided platform; on one side, health care organizations, which usually include laboratories and radiology centers along with major hospital systems and pharmacies, join the platform and *upload* their patients' data to the RHIO's database. On the other side of the platform, medical providers query RHIO's database and *download* the available medical information. The RHIO provides IT infrastructure and manages patient privacy and data transactions between the members (Yaraghi et al. 2013, 2014, 2015).

1 Some parts of the text in this report are borrowed from my article forthcoming at the Journal of American Medical Informatics Association : "An Empirical Analysis of the Financial Benefits of Health Information Exchange in Emergency Departments"

2 There are two other approaches to health information exchange: *patient mediated exchange* and *directed exchange*. In the former, patients directly manage an electronic archive of their medical records and provide different entities with access to their data. In the latter, a pair of medical providers can exchange a patient's medical data via a secure message sent over the internet.

Despite the potential benefits of RHIOs and significant support from the federal and state governments, most of them have not been able to bring enough medical providers on board and still do not have a sustainable business model (Adler-Milstein et al. 2013). Moreover, the studies on the effectiveness of health information exchange in general and RHIOs in particular are not conclusive and we still do not know how exactly information exchange affects the cost and quality of health care services (Rudin et al. 2014; Rahurkar et al. 2015).

Why are medical providers reluctant to join health information exchange (HIE) platforms[3]? Why is there little evidence on the effectiveness of HIE platforms? How much can HIE platforms affect the efficiency of health care services? I have previously answered the first question and discussed the economic barriers to health information exchange (Yaraghi 2015a). I proposed a business model that aligns the economic incentives of different medical providers to drive them to join HIE platforms and actively exchange the medical data of their patients with each other. In this report, I answer the last two questions. I argue that the potential value of a RHIO is proportional to two conditions: (1) its volume of available medical data and (2) the extent to which its members access the available data. I review the studies that examine the effectiveness of health information exchange initiatives and discuss that in many cases at least one of these two conditions is not met. I then present the results of a study on the effects of accessing patient information through an HIE platform on the number of the laboratory tests and radiology examinations performed in two emergency departments in Western New York. In this study, the above conditions are met: (1) it is done in a setting where there is a wealth of available medical data for each patient and (2) the database of HIE platform is being queried in 100 percent of patient encounters. In the first ED setting, querying RHIO's database is associated with respectively, a 25 percent and 26 percent reduction in the estimated number of laboratory tests and radiology examinations. In the second ED setting, querying RHIO's database is associated with a 47 percent reduction in the estimated number of radiology examinations.

WHY IS THERE LITTLE EVIDENCE ON THE EFFECTIVENESS OF HIE PLATFORMS?

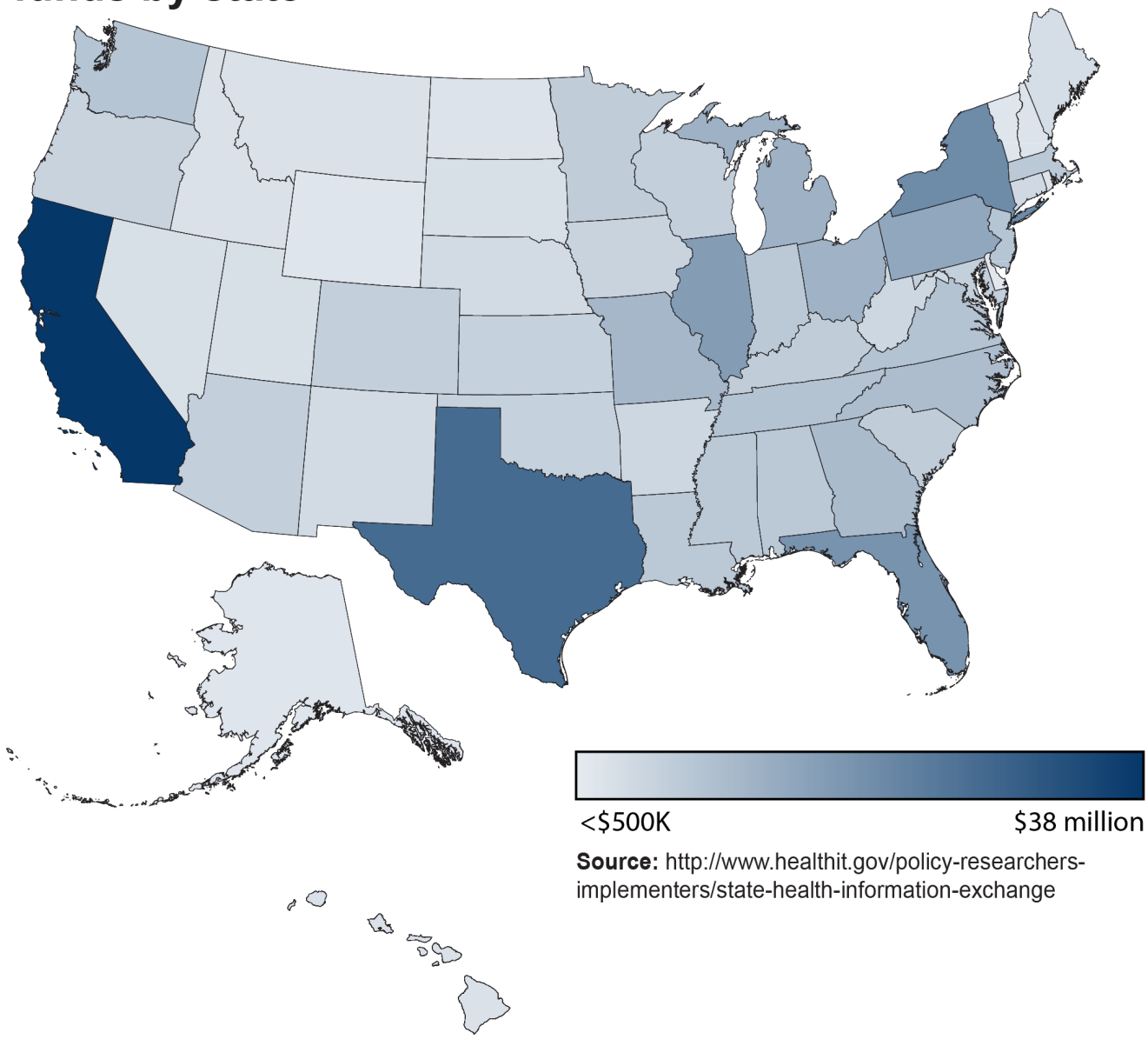
The Office of National Coordinator for Health IT has awarded $548 million to 56 governments including states, eligible territories, and qualified state-designated entities (SDE) to establish their own health information exchange (HIE) platforms. How has this investment paid off? The literature does not provide a clear answer to this question. In the following, I discuss the reasons for the lack of evidence on the effectiveness of HIE platforms.

First, the volume of electronic medical data grows over time as more providers adopt electronic health records (EHR) solutions and capture their patients' data in electronic format. When more medical providers join an HIE platform and share their data with others, its effect on cost and quality of health care services will become more salient. Studies on the effectiveness of RHIOs have mostly occurred during the early development stages of these platforms when only a small proportion of medical data providers had joined the system and thus the volume of available data on these platforms has only been a fraction of the currently available data. A RHIO without data is an expensive yet empty glass of water. At the beginning, RHIOs could help physicians have a better understanding of the patients' condition as much as an empty glass could help them quench their thirst.

Second, physicians seldom query the RHIO database. It is not a random event and instead is decided by physicians based on a set of patient- and physician-specific factors. For example, technologically savvy physicians are more

3 Although a RHIOs is just one of the possible forms of an HIE platform, in this report I use the terms "HIE platform" and "RHIO" interchangeably.

Figure 1: The state HIE cooperative agreement program funds by state



Source: http://www.healthit.gov/policy-researchers-implementers/state-health-information-exchange

likely to query an HIE platform. These physicians may systematically practice medicine differently from others and thus the differences in the care outcomes that their patients experience may not be necessarily attributed the HIE use. In the studies of Vest et al. (2014a) and Frisse et al. (2012) RHIOs database was queried in respectively 5.79 percent and 6.8 percent of emergency department (ED) encounters. Although the authors appropriately use propensity score matching techniques to adjust for the endogeneity of HIE use, their conclusions may still be affected by the inherent and inevitable limitation of these techniques. Also, the very low level of encounters with HIE use may be a partial reason for why no statistically significant difference in the number of laboratory tests were observed in those studies. Confounding factors further obscure the conclusions of previous research. These are the factors that may affect both the level of HIE use and care outcomes, yet are commonly unobserved and are not accounted for. Quality of medical technologies, geographical regions, managerial policies, and technology savviness of physicians are examples of such factors. For instance, ED settings in affluent areas may have more financial resources

to allocate to HIE efforts and thus will have a higher level of HIE use. At the same time, the patients who visit these ED settings may be more compliant with the advice of ED physicians and thus experience better care outcomes. On the other hand, the EDs that are located in less affluent areas may also have fewer resources to allocate to HIE and as a result have a lower level of HIE usage. The patients who visit these EDs may also have lower medical compliance levels and thus experience worse care outcomes. By regressing the care outcomes on the level of HIE use, one would overestimate the effects of HIE and attribute the effects of unobserved patient characteristics to the HIE usage. In the appendix, I discuss how each of the above mentioned factors have affected the conclusions of previous research on effectiveness of HIE platforms.

HOW MUCH CAN HIE PLATFORMS AFFECT THE EFFICIENCY OF HEALTH CARE SERVICES?

In this section I present the results of an empirical analysis on the effects of accessing patient information through an HIE platform on the number of the laboratory tests and radiology examinations performed in two ED settings in Western New York. The design of this trial allows me to address the above mentioned gaps and identify the causal effects of querying a RHIOs database on care outcomes. First, almost all of the medical data providers (laboratories, radiology centers, hospitals and pharmacies) have already joined the RHIO in this study and thus its members can have access to a nearly comprehensive medical history of their patients. As I discussed before, the wealth of available medical data on the RHIO increases its value and potential impact on various health care measures. Second, this trial is focused on only two EDs[4] over a short period of time and thus its results do not suffer from possible confounding and unobserved factors. The design of this study ensures that the decision to query RHIO's database is exogenous and is not driven by either patient or physician characteristics. These features allow me to establish a stronger causal link between querying RHIO's database and patient outcomes.

DESIGN

Two identical trials were conducted in two ED settings over the periods of Aug. 4, 2014 to Sept. 26, 2014 and Oct. 20, 2014 and Dec. 8, 2014 to assess the effects of querying the database of an HIE platform on the number of orders for laboratory tests and radiology examinations. A group of medical liaisons led by an experienced registered nurse were trained on how to access RHIO's database and query clinically relevant information from a patient's medical history. The ED providers were fully informed and their consent was acquired prior to the study. The medical liaisons were instructed not to interfere with the treatment process of the ED providers and only inform them about the medical information of the patients that were accessible on RHIO's database. The liaisons could only access the medical records of the patients who had previously provided written consent to share their records for medical treatment and research purposes. The medical information that was accessed included previous laboratory results, radiology examinations, hospital admissions and discharge transcripts, operative reports, and medication history. During their presence at the ED settings, the medical liaisons queried the HIE database for all of the patient encounters and provided the ED clinicians with the relevant medical information. Hereafter I use the term "*treatment group*" to refer to the patients whose care involved querying the RHIOs database. Similarly, I use the term "*control group*" to refer

4 I present the results for each ED separately.

to the patients whose care did not include an HIE query.[5] These are the patients who had visited the ED during the times when medical liaisons were not present and RHIO's database was not queried.

The results of a similar version of this trial in a different ED setting is accepted for publication in the Journal of the American Medical Informatics Association (Yaraghi 2015b). In the previous trial, the medical liaisons shadowed a specific group of clinicians during *all* of their working shifts (including evening and night shifts). The utilization trends of these clinicians were then compared with those of other clinicians in the same ED setting. That is, the patients in the control and treatment groups were treated by different physicians. However, in this study the patients in the control group are treated by the same ED clinicians who treated patients in the treatment group. This feature further ensures that physician-level characteristics do not drive the differences in the outcome measures.

SETTING

The trials were conducted by HEALTHeLINK, the RHIO of Western New York as internal quality improvement projects[6]. HEALTHeLINK provides fully operational query-based HIE services to over 3,300 members in Western New York. All of the major medical data providers in the region have already joined the platform. When a patient provides consent, HEALTHeLINK subscribers will have access to the medical records through either a fully automated system, which pushes the medical data into their interoperable electronic medical records (EMR) systems or through a web portal in which they can search for the available medical history of their patients. Both of the EDs in this study has access to the HIE services via this web portal.[7]

Both of the ED's reside in an urban setting. While primarily servicing a diverse population of lower socioeconomic status, they also attract a suburban population due to their reputation as regional centers of excellence for certain conditions.[8]

STUDY POPULATION

Four hundred and forty-nine patients visited the first ED during the times when the medical liaisons were present. The same clinicians in the same ED treated 399 patients when the liaisons were not present. In the second ED, 303 patients were treated while the medical liaisons were presents and 418 were treated by the same clinicians when the liaisons were not present. For each patient in either of the two groups, the de-identified HIE log files were collected since one year prior to the ED admission date until the discharge date from ED. The medical histories of the patients were determined based on this dataset. It was also used to measure the number of laboratory tests and the radiology examinations which were performed during the study. In the next section, I provide detailed descriptions of these variables.

5 To be included in the study, the patients are chosen based on a convenience sampling method and thus although I use familiar terms of "treatment" and "control" groups, one should be reminded that this is *not* a completely randomized controlled trial.

6 I only had access to the deidentified data.

7 I serve as the Scientific Advisor of HEALTHeLINK. I am not financially compensated by HEALTHeLINK.

8 The EDs requested to remain anonymous.

MEASURES

The outcome measures are the number of the laboratory tests and radiology examinations that are performed during the ED visit. The main independent variable of interest is *HIE.* This is a dichotomous variable that is equal to one if the patient was in the treatment group and the RHIO's database was queried during treatment. The HIE is equal to zero if the patient was in the control group and his or her care did not include querying the RHIO's database. The control variables includes the gender and years of experience of ED clinician in addition to the average number of hospital transcriptions, laboratory tests, and radiology examinations that were ordered on behalf of the patient since one year before the start date of the trial study. Since I do not have access to the initial diagnosis codes, the prior medical history of the patients is used as a proxy for their overall medical condition. Those patients for whom at least one of these control variables is missing are removed from the analysis sample. Descriptive statistics on the remaining patients in both treatment and control groups in the first and second ED are presented in tables (1) and (2) respectively.

Table 1: Patient characteristics in the first ED

Variable	Treatment group N=310		Control group N=278		$H_0: \mu_C-\mu_T = 0$
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**t-value**
Laboratory tests during the study	22.10	42.52	21.45	38.28	-0.19
Radiology exams during the study	3.12	3.99	3.68	4.43	1.59
Transcriptions during the study	1.45	2.14	1.54	2.11	0.54
Prior laboratory tests	23.67	60.64	16.80	40.82	-1.59
Prior radiology examinations	2.39	5.04	1.82	3.68	-1.55
Prior transcriptions	1.53	3.79	1.22	2.96	-1.08

***: significant at p<0.01; **: significant at p<0.05; *: significant at p<0.1

Table 2: Patient characteristics in the second ED

Variable	Treatment group N=157		Control group N=381		$H_0: \mu_C-\mu_T = 0$
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**t-value**
Laboratory tests during the study	12.68	45.95	27.41	45.13	4.35***
Radiology exams during the study	1.14	2.95	3.92	5.07	9.58***
Transcriptions during the study	0.27	1.04	1.86	2.51	10.48***
Prior laboratory tests	28.46	96.35	27.09	83.60	-1.47
Prior radiology examinations	1.84	4.10	2.27	4.95	-0.65
Prior transcriptions	1.25	3.10	1.82	4.49	1.07

***: significant at p<0.01; **: significant at p<0.05; *: significant at p<0.1

Table 3: The effect of HIE on reducing the number of procedures performed during the visits in the first ED

Parameter	Panel 1 (Laboratory tests)	Panel 2 (Radiology exams)
Intercept	1.623566***	0.527728***
	(0.158803)	(0.124713)
HIE	-0.287184***	-0.273505***
	(0.099935)	(0.084821)
Clinician's gender (female=1)	-0.280342**	0.081176
	(0.117555)	(0.096844)
Clinician's years of experience	-0.007474*	-0.002599
	(0.004498)	(0.003686)
Clinician's prior lab orders per patient	0.060276***	0.006609
	(0.009349)	(0.006220)
Clinician's prior radiology orders per patient	-0.169676*	0.133527*
	(0.092845)	(0.072572)
Clinician's prior hospital orders per patient	0.706195***	0.419565***
	(0.172383)	(0.108514)
Patient's prior laboratory tests	0.003425**	-0.001874
	(0.001529)	(0.001115)
Patient's prior radiology examinations	0.009584	0.039600**
	(0.020250)	(0.016161)
Patient's prior hospital transcriptions	0.004806	0.019996
	(0.025921)	(0.021469)
Dispersion coefficient	1.289118	0.666471***
	(0.088900)	(0.063363)

***: significant at p<0.01; **: significant at p<0.05; *: significant at p<0.1

ANALYSIS

Since the dependent variables are considered count data and can only take non-negative integer values, I apply a negative binomial regression model to investigate the effects of accessing HIE on the *number* of laboratory tests and radiology examinations ordered during a patient's visit to the ED.[9] I hypothesize that the coefficient of *HIE* variable is negative and expect that holding all of the other variables constant, accessing HIE would reduce the number of laboratory tests and radiology examinations performed during the patient's ED visit.

9 As shown in tables 3 and 4, the dispersion coefficient is always positive and significant. Since the response variable is over-dispersed it will not fit a Poisson distribution.

Table 4: The effect of HIE on reducing the number of procedures performed during the visits in the second ED

Parameter	Panel 1 (Laboratory tests)	Panel 2 (Radiology exams)
Intercept	1.257826***	0.310739**
	(0.203803)	(0.134417)
HIE	0.025511	-0.641098***
	(0.213439)	(0.148651)
Clinician's gender	-0.107249	0.041064
(female=1)	(0.164356)	(0.118712)
Clinician's years of	0.011292	0.001494
experience	(0.007466)	(0.004959)
Clinician's prior lab orders	0.021967***	0.006296*
per patient	(0.006180)	(0.003251)
Clinician's prior radiology	0.216760**	0.279632***
orders per patient	(0.091098)	(0.050701)
Clinician's prior hospital	0.392107**	0.109959
orders per patient	(0.161079)	(0.082239)
Patient's prior laboratory	0.002638	0.000670
tests	(0.001196)	(0.000746)
Patient's prior radiology	-0.014315	0.024577
examinations	(0.033480)	(0.016316)
Patient's prior hospital	0.087232**	0.013911
transcriptions	(0.038134)	(0.020689)
Dispersion coefficient	2.407084***	0.851958***
	(0.164099)	(0.086205)

***: significant at p<0.01; **: significant at p<0.05; *: significant at p<0.1

$$Log(\mathrm{E}(Procedure_i))=\beta \mathrm{HIE}_i+ \mathbf{C'}_i\boldsymbol{\delta} \qquad (1)$$

In the above specification, *procedure* is the number of either laboratory tests or radiology examinations. $\mathbf{C}_i$ is a vector of controls for medical history and clinician characteristics for patient as described in the previous section. Note that equation (1) is estimated for laboratory tests and radiology examinations separately. The results of estimating equation (1) based on the data from the first and second trials are presented in tables (3) and (4) respectively. In both tables, the first panel represents the effects of *HIE* along with other control variables on reducing the number of laboratory tests. The second panel represents the effects of the same set of variables on the number of radiology examinations.

RESULTS

The first panel of table (3) presents the results of analyzing the effects of querying RHIO's database on the number of laboratory tests performed on the patients in the first ED. The second panel of table (3) presents the effects of the same factors on the number of radiology examinations.

According to the first panel of table (3) after controlling for the provider and patient characteristics, the expected log count of laboratory tests decreases by 0.7248 units for patients in the treatment group. This implies that the number of laboratory tests is expected to reduce by 25 percent in patients for whom the RHIO's database is being queried.[10] The second panel of table 2 presents the effects of querying RHIO's database on the number of radiology examinations created for patients during the ED visit. Ceteris paribus, the expected log count of radiology examinations decreases by 0.2735 units for patients in the treatment group. This implies that the number of radiology examinations is expected to reduce by 26 percent in patients for whom their care includes querying the RHIOs database.[11]

The first panel of table (4) presents the results of analyzing the effects of querying RHIO's database on the number of laboratory tests performed on the patients in the second ED. The second panel of table (4) presents the effects of the same factors on the number of radiology examinations. While querying RHIO's database does not affect the total number of laboratory test orders[12], it has a salient effect on the number of orders for radiology examinations. According to the second panel of table (4) after controlling for the provider and patient characteristics, the expected log count of radiology examinations decreases by 0.6411 units for patients in the treatment group. This implies that the number of radiology examinations is expected to reduce by 47 percent in patients for whom their care includes querying RHIO's database.[13]

LIMITATIONS

Findings of this research may not be generalizable to other areas because HEALTHeLINK has very high and longstanding participation rates among ambulatory providers and the major sources of clinical data. As such, the information available on the HIE platform represents a fairly comprehensive and longitudinal record. Since the potential benefits of an HIE platform is proportionate to the volume of clinical data that can be accessed on it the similar effects may not be observed in other settings. Another limitation to the external validity of this study is the use of the medical liaisons. Not all other HIE efforts will have staff dedicated to facilitate provider access to information.

Since I did not have access to initial diagnosis codes or the acutely level of patients, I could not directly control for these measures. To overcome this limitation, the number of previous medical records and hospitalizations are used a proxy for adjusting the differences in the risk levels among patients. Moreover, ethical considerations prevent fully randomized access to RHIO's database. I therefore eliminated the rare instances where patients in the control group included provider access to RHIO's database. Although this introduces some bias in the study, the bias will only lead to underestimation of the HIE coefficient in the model.

10 $\log(^{HIE}/_{noHIE}) = -0.2871 \rightarrow {}^{HIE}/_{noHIE} = 0.75$

11 $\log(^{HIE}/_{noHIE}) = -0.2735 \rightarrow {}^{HIE}/_{noHIE} = 0.74$

12 Laboratory tests are not static and can change minute to minute so past results, while valuable in determining a baseline, may not prevent additional testing in patients with cardiac and neurovascular issues.

13 $\log(^{HIE}/_{noHIE}) = -0.6411 \rightarrow {}^{HIE}/_{noHIE} = 0.53$

CONCLUSION

The efforts by Congress, patient advocacy groups, and most importantly the shift towards value based payments promise complete interoperability in the near future. After more than a decade of concerted national efforts, we are now on the verge of realizing the returns on our investments on health IT. HIE platforms have the potential to leverage the national investments on interoperability and radically improve the efficiency of health care services.

To have a clear understanding about the benefits of HIE platforms, the volume of available data and the investments by medical providers to meaningfully engage in HIE should be taken into account. This is the first study in which access to an HIE platform was provided to all of the patients in a treatment group, while the care of the others in the control group did not include querying an HIE platform. Moreover, due to the high participation rate of providers of medical data, a relatively comprehensive medical history of patients was available on the RHIO's database. Due to this feature of the trial design, endogeneity and confounding effects are avoided and thus a causal link between querying RHIO's database and outcome measures can be established. According to this analysis, querying RHIO's database is associated with significant utilization reduction in ED settings. In the first ED setting, querying RHIO's database is associated with respectively, a 25 percent and 26 percent reduction in the estimated number of laboratory tests and radiology examinations. In the second ED setting, querying RHIO's database is associated with a 47 percent reduction in the estimated number of radiology examinations.

This study also highlights the importance of designing efficient workflows in which accessing an HIE platform is integrated in the routine procedures of providing care at ED settings. The rate of access to HIE platforms in the treatment group was artificially held at 100 percent and is considerably above the typical HIE access rates in other ED settings. This was made possible by hiring liaisons who were only focused on querying and filtering RHIO's database and provided the clinicians with the relevant medical data. The results of this study enables other ED settings to evaluate the benefits of increasing their HIE querying rate against its potential costs. Moreover, the potential benefits of increased access to HIE platforms calls for more detailed studies on efficient strategies and workflow designs which enable ED clinicians to access HIE in smoother and user friendlier manners.

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APPENDIX: A BRIEF REVIEW OF PREVIOUS STUDIES ON THE EFFECTS OF HIE PLATFORMS ON CARE OUTCOMES:

Overhage et al. (2002) conduct a randomized control trial to analyze the effects of accessing patient information provided by another hospital on the total ED charges as well as repeat orders of specific tests in two settings. While they observe a significant decrease in total charges in ED setting, they do not observe significant reductions in the number of repeated tests. They completed their study in 1996 and their intervention included access to the medical records that were provided by only one hospital. Vest (2009) studies the association between the access rates to an HIE platform and the ED visits and inpatient hospitalizations over a period of two and a half years in a group of 6,114 patients in Texas. According to his analysis, the HIE access is strongly associated with significant increases in frequency of ED visits and hospitalizations. While this is an unexpected observation, it highlights the role of confounding factors that if unadjusted for, can significantly obscure our understanding of the effects of HIE access. As Vest (2009) himself puts it, "factors potentially indicative of complex cases, or in other words simply sicker people, increased the odds of providers accessing the HIE information". In other words, the medical condition of the patient was determining both the chance of HIE access and also the chance of hospitalization or repeated ED visit. In a similar study, Bailey et al. (2013a) examine the association between the HIE use and repeated radiology images for patients with back pain. Although in this context, HIE is shown to have a positive impact on reducing the number of images, the confounding factors affect the conclusions of Bailey et al. (2013a) in similar way that they affect the conclusions of Vest (2009). Hansagi et al. (2008) examine whether having access to medical histories of frequent ED users would decrease their subsequent visits to ED. Although in 82 percent of the cases providers deemed such information useful, the authors do not observe any significant differences in the number of ED visits and other utilization measures. Similarly, Proeschold-Bell et al. (2010) conduct a randomized trial to examine the association between information exchange and patient health outcomes across a group of human immunodeficiency virus (HIV) care providers. Their treatment group includes the patients whom their information was exchanged with case managers and care providers. Similar to the study of Hansagi et al. (2008), despite the fact that "most providers indicated perceived value in the set of information exchanged", Proeschold-Bell et al. (2010) did not observe significant differences in health outcomes between the control and intervention groups. These seemingly contradictory findings can be attributed to the fact that authors did not study the effects of information exchange at individual patient level and rather compared the averages of the outcome measures between the control and intervention groups. Unless the HIE effect is studied at patient's level, the effects of individual level characteristics cannot be parsed out from the pure effects of information exchange. Although the medical providers in the studies of Hansagi et al. (2008), Proeschold-Bell et al. (2010) and Ross et al. (2013) had access to patient histories, one cannot be sure that such information was adequately reviewed and actually used to make medical decisions; this question also remains to be answered in some of the studies that report positive outcomes from HIE access. For example, Mäenpää et al. (2011) report that the number of radiology examinations decreases after HIE adoption in Finland, Hebel et al. (2012) report a significant decrease in the number of laboratory tests in a large population of patients in two academic hospitals in the US, and Wilcox et al. (2012) report that improved technical quality of an HIE systems is associated with a significant drop in hospitalizations after ED visit. However, a causal link between HIE adoption and utilization levels cannot be stablished in neither of the mentioned studies unless one can rule out all of the confounding factors and ensure that the HIE adoption necessarily led to HIE usage. Observational studies that use propensity score matching to create a comparable control group of patients are amongst the most recent and successful approaches to bridge the above mentioned empirical limitations. The research by Tzeel et al. (2011), Vest et al. (2014a) and Frisse et al. (2012) are examples of such studies, interestingly, all of them report a direct association between HIE usage and efficiency measures at ED settings.

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