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Authors

Adler-Milstein, Julia
Linden, Ariel
Hsia, Renee
et al.

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Electronic connectivity between hospital pairs: impact on emergency department-related utilization

Julia Adler-Milstein, PhD[1,*], Ariel Linden, DrPH[1], Renee Y. Hsia, MD, MSc[2], Jordan Everson, PhD[3]

[1]Division of Clinical Informatics and Digital Transformation, Department of Medicine, University of California, San Francisco, San Francisco, CA 94131, United States, [2]Department of Emergency Medicine, University of California, San Francisco, San Francisco, CA 94110, United States, [3]US Department of Health and Human Services, Office of the National Coordinator for Health IT, Washington, DC 20201, United States

*Corresponding author: Julia Adler-Milstein, PhD, Division of Clinical Informatics and Digital Transformation, Department of Medicine, University of California, San Francisco, 10 Koret Way, 3rd Floor, San Francisco, CA 94131 (julia.adler-milstein@ucsf.edu)

Abstract

Objective: To use more precise measures of which hospitals are electronically connected to determine whether health information exchange (HIE) is associated with lower emergency department (ED)-related utilization.

Materials and Methods: We combined 2018 Medicare fee-for-service claims to identify beneficiaries with 2 ED encounters within 30 days, and Definitive Healthcare and AHA IT Supplement data to identify hospital participation in HIE networks (HIOs and EHR vendor networks). We determined whether the 2 encounters for the same beneficiary occurred at: the same organization, different organizations connected by HIE, or different organizations not connected by HIE. Outcomes were: (1) whether any repeat imaging occurred during the second ED visit; (2) for beneficiaries with a treat-and-release ED visit followed by a second ED visit, whether they were admitted to the hospital after the second visit; (3) for beneficiaries discharged from the hospital followed by an ED visit, whether they were admitted to the hospital.

Results: In adjusted mixed effects models, for all outcomes, beneficiaries returning to the same organization had significantly lower utilization compared to those going to different organizations. Comparing only those going to different organizations, HIE was not associated with lower levels of repeat imaging. HIE was associated with lower likelihood of hospital admission following a treat-and-release ED visit (1.83 percentage points [−3.44 to −0.21]) but higher likelihood of admission following hospital discharge (2.78 percentage points [0.48-5.08]).

Discussion: Lower utilization for beneficiaries returning to the same organization could reflect better access to information or other factors such as aligned incentives.

Conclusion: HIE is not consistently associated with utilization outcomes reflecting more coordinated care in the ED setting.

Key words: health information exchange; health care utilization; emergency department; health information interoperability; claims analysis.

Background and significance

There is substantial evidence that fragmented health care—particularly admissions or emergency department (ED) care at multiple hospitals—leads to negative health outcomes.[1] Electronic health information exchange (HIE) is a key national strategy to improve fragmented care by ensuring that care teams have access to more timely and complete patient records.[2,3] Yet multiple evidence reviews on HIE impact have concluded that these benefits are inconsistently realized.[4–8] These reviews also characterize the evidence as low-quality and point to specific shortcomings. Many studies measure HIE as an exposure at the individual organization level (ie, hospital X does or does not participate in HIE), which is problematic because it does not reflect underlying variation in which a given hospital may connect to some hospitals via an HIE network but not others. A more precise measure would capture whether pairs of hospitals that treat the same individual are or are not connected by participating in the same HIE network. Some studies have addressed this issue by employing the use of HIE on an individual patient as the primary exposure. However, this approach is biased if HIE use is related to patient status. Further, these studies are limited to single institutions or HIE networks, and therefore may not generalize. Finally, the majority of studies were published before 2015, and more timely evidence is useful given the evolution of HIEs.

Given the large and ongoing public and private-sector investments in HIE, including current efforts under the 21st Century Cures Act, there is a need for assessments of HIE impact that better address these shortcomings. If we fail to find evidence of lower utilization using a more robust empirical approach, it suggests the need to rethink how policies, technical capabilities, and organizational priorities are interacting to translate now widespread HIE capabilities into better patient outcomes. Particularly given the persistence of fee-for-service reimbursement, it is very possible that organi-

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zations have adopted HIE to meet federal requirements but are not routinely using the capabilities to improve efficiency and quality.[9,10]

Objective

Our study sought to advance the evidence on HIE impact by taking a novel approach that combines: (1) more precise measures of HIE participation between pairs of organizations where individuals were treated; (2) not relying on use of HIE as an exposure, and (3) leveraging a national sample. Specifically, we used 2018 national Medicare claims data to identify beneficiaries that visited 2 unaffiliated EDs and compared outcomes based on whether or not the 2 organizations were connected to the same HIE network(s). To enhance the value of the results, we also identified a third group of beneficiaries that returned to the same ED, which serves as a useful reference point against which to compare fragmented care with HIE. We focused on HIE in the ED setting, a fast-paced, high-pressure environment where there is greater uncertainty about the clinical severity of incoming patients and where comprehensive patient health information can play a critical role in quality of care and patient outcomes.[11] Prior literature on ED physicians' perceptions of the need for HIE suggests that HIE has the potential to benefit patient care and the efficiency of health care delivery.[12] These beliefs are supported by evidence that HIE adoption is associated with improved ED utilization rates, LOS, and 30-day readmission.[11,13–15]

Materials and methods

Context

HIE generally refers to the electronic exchange of patient records across disparate electronic health record systems (EHRs). There are ∼100 regional/local health information organizations that facilitate HIE (usually covering one or more counties or entire states), several large national HIE networks that span multiple states (eg, Collective Medical's EDHIE), and additional HIE networks led by EHR developers (eg, Epic's Care Everywhere network). Hospital participation in any HIE network is optional (though indirectly incentivized through the Promoting Interoperability Program and in some cases directly incentivized at the state level), and the decision to participate is distinct but related to their choice of EHR developer. For instance, most regional HIE networks are not directly tied to any EHR, while some developers default their customers into their proprietary HIE network and into some national networks. The result is a patchwork of connected health care organizations in which most hospitals participate in more than one method of exchanging information but nevertheless report difficulty accessing information from outside organizations.[16]

Data sources

To measure the specific HIE network(s) in which each hospital participated in 2018, including health information organizations, EHR developer networks, and national networks, we used data from Definitive Healthcare data (formerly HIMSS Logic Data) and the AHA IT Supplement Survey. These data were also used to capture hospital characteristics. We used a third source of data—Medicare claims data (20% standard files: MedPAR, outpatient, carrier)—to identify beneficiaries with multiple encounters (ED visits and/or admissions, depending on measure) and beneficiary characteristics. We used 2018 data because this was the most recent year for which claims data were available when we started our analyses. Our study was approved by the UCSF IRB.

Sample definition and utilization outcome measures

We selected utilization outcome measures that we hypothesized would be impacted by the ability of a frontline ED team to access patient records from a prior ED visit or hospitalization. These measures have also been examined in the HIE impact literature.[4–6,11,13,14]

We created 2 versions of each measure for those 65 years and older, defined by whether the first and second encounter happened within 30 days or, alternatively, within 7 days of one another. We consider the 30-day measure as our primary measure given its relevance to policy programs[17] while the 7-day measure may be more sensitive to the impact of HIE. Summaries of each utilization outcome are as follows with details on measure specifications and claims files used in the Technical Appendix.

Measure 1: repeat imaging

This measure captured all beneficiaries with 2 ED visits within 30 or 7 days who had an imaging study during the first ED visit to ensure there was an opportunity for repeat imaging during the second ED visit. Imaging was defined as 12 dichotomous variables representing whether or not the ED visit included one or more computed tomography (CT) scans, or separately magnetic resonance images (MRIs), of 6 distinct body regions (eg, CT of head, neck, or spine[18–21] was one category) using CPT codes (see Technical Appendix). We then constructed the same 12 measures (2 imaging modalities for 6 distinct body regions) for the second ED visit and considered repeat imaging to have occurred if one or more of the 12 aligned dichotomous variables both had a value of 1. For example, if both encounters had at least 1 CT of head, neck, or spine, then this was considered repeat imaging, but if the first had a CT of head, neck, or spine and the second had an MRI of head, neck, or spine, then this was not considered repeat imaging. We measured whether any repeat imaging occurred across the 12 possible measures.

Measure 2: admit from ED following ED visit

This measure captured all beneficiaries with a treat-and-release ED visit followed by a second ED visit within 30 or 7 days. We measured whether or not the beneficiary was admitted to the hospital during the second ED visit.

Measure 3: admit from ED following hospital discharge

This measure captured all beneficiaries with a hospital discharge followed by a second ED visit within 30 or 7 days. We measured whether the beneficiary was admitted to the hospital from the second ED visit. While this measure resembles a readmission measure, it is not identical because we require that a subsequent ED visit first occur, thereby limiting the denominator to those with a subsequent ED visit as opposed to all those discharged from the hospital.

We defined 3 distinct samples at the beneficiary level—one for each of our outcome measures based on the beneficiaries who met the inclusion criteria for the measure (outcome measure datasets). A given beneficiary may have multiple instances in the calendar year of meeting the measure definition and we included all of them, such that each "pair" for a

Table 1. Sample characteristics (2018): 30-day measures, for beneficiaries over 65.

Measure definition	Repeat imaging (out of 12 possible) For beneficiaries that had 2 treat-and-release ED visits within 30 days of each other, did the beneficiary have any repeat imaging (same modality, same body region) during the second ED visit	Admit from ED following ED visit For beneficiaries that had an index treat-and-release ED visit and a second ED visit within 30 days, did the beneficiary get admitted during the second ED visit	Admit from ED following hospital discharge For beneficiaries that that had an index hospitalization and a subsequent ED visit within 30 days, did the beneficiary get admitted during the second ED visit
Different orgs, no HIE: no. of pairs of organizations not on same HIE network (directional)	982	2470	1402
Different orgs, HIE: no. of pairs of organizations on same HIE network (directional)	1998	4621	3046
Same org: no. of pairs where first and second organization are the same	1632	1670	1605
Beneficiary characteristics			
Number of unique beneficiaries	41 177	134 864	31 706
Number of observations	58 105	239 514	39 702
Average age of beneficiaries (SD)	78.15 (8.67)	77.59 (8.59)	75.98 (7.85)
Dual eligibles (%)[a]	30.19	31.61	24.98
Female (%)[b]	59.79	56.07	50.52
Race (%)[b]			
Asian	1.09	1.12	1.25
Black	10.65	13.04	11.98
Hispanic	1.94	1.83	2.01
North American Native	0.62	0.59	0.51
Other	1.03	1.18	1.29
Unknown	0.90	0.96	1.15
White	83.76	81.27	81.80
Relative frequency of 5 most common comorbidities (%)[c]			
Hypertension, uncomplicated	87.0%	87.0%	86.4%
Cardiac arrhythmias	56.3%	59.7%	66.7%
Fluid and electrolyte disorders	53.1%	57.9%	66.6%
Hypertension, complicated	42.5%	48.8%	57.9%
Chronic pulmonary disease	42.3%	46.4%	51.0%

[a] For at least 1 month in 2018.
[b] Categories from the Medicare enrollment file.
[c] From all diagnosis fields across inpatient, carrier, and outpatient files. Abbreviations: ED, emergency department; Org., organization; HIE, health information exchange.

given beneficiary represents one observation. The distribution of the number of observations per beneficiary per measure is reported in Appendix Table S1. Across outcomes, 92.0%-99.5% of beneficiaries had 3 or fewer observations.

Exposures

The primary exposure captured whether a beneficiary's second encounter occurred at a different organization that was connected by HIE (ie, both organizations participated in the same HIE network(s)), or at a different organization that was not connected by HIE. We also examined a third group as a reference—those for which the second encounter occurred at the same organization as their initial encounter. To categorize beneficiaries, we identified whether the Medicare Provider Numbers (MPNs) for the first and second utilization events were the same. When they occurred at organizations with different MPNs, we matched MPNs to a separate dataset that measured which hospitals were and were not connected via an HIE network(s). This dataset was constructed using Definitive Healthcare and AHA IT Supplement Survey data that capture the specific HIE network(s) in which each hospital participates. Definitive Healthcare collects data from hospital CIOs annually about varied dimensions of health IT infrastructure, including any local/regional HIE networks and EHR developer HIE networks[22] in which they participate. The AHA IT Supplement captures annual information on hospitals' participation in national HIE networks. We had complete participation data on 1721 hospitals (out of 4518 non-federal, acute care hospitals; see Technical Appendix for details including our approach to missing HIE participation data).

To determine whether 2 hospitals participated in the same HIE network, we first identified pairs of hospitals that cared for a shared set of patients. Specifically, we used 2018 DocGraph HOP data that includes pairs of hospitals that treated more than 10 of the same Medicare beneficiaries over the course of a year (pairs of hospitals with 10 or fewer shared beneficiaries were removed from the DocGraph data due to

Medicare cell suppression rules). We removed pairs that included hospitals in the same multi-hospital system in the AHA Annual Survey because these pairs were likely to use the same instance of an EHR and not rely on an HIE network. We merged pair-level data with HIE participation data and defined pairs of hospitals as connected if they participated in one or more of the same networks and not connected otherwise. We only included pairs of organizations when we knew the HIE status of BOTH organizations in 2018. Finally, we merged the pair-level data (limited to pairs with known HIE participation status) with each beneficiary-level outcome measure dataset.

We adjusted for potential confounders as captured by beneficiary and hospital covariates. Beneficiary covariates included age, gender, race, dual-eligible status, and individual Elixhauser comorbidity categories.[23] The first 4 came from the Medicare Enrollment File while comorbidities were calculated based on all diagnosis fields across inpatient, carrier, and outpatient files. Hospital covariates included ownership, teaching status, system membership, critical access status, trauma center status, rurality, percent Medicaid volume, participation in capitated reimbursement, risk-based contract, bundled payment, Accountable Care Organization, clinically integrated network, or population health collaboration (see Appendix Table S2); these measures were included separately for each hospital in the pair.

Analytic approach

We calculated descriptive statistics for our sample, separately for each of the 3 outcomes since they had their own sample. We also calculated each outcome measure by category of how the 2 organizations were related: different organizations without HIE (Different-No HIE), different organizations with HIE (Different-HIE), and same organization (Same) reference group. Lastly, we estimated multivariable regression models controlling for beneficiary and organization characteristics to compare the 3 organization relationship categories for each outcome, thereby assessing whether "different-HIE" hospitals had lower levels of repeat imaging and lower likelihood of hospital admission during the second ED visit as compared to "different-no HIE" hospitals (as well as to "same"). Specifically, we estimated multi-level mixed models with cross

Table 2. Sample characteristics (2018): 7-day measures, for beneficiaries over 65.

Measure definition	Repeat imaging (out of 12 possible) For beneficiaries that had 2 treat-and-release ED visits within 7 days of each other, did the beneficiary have any repeat imaging (same modality, same body region) during the second ED visit	Admit from ED following ED visit For beneficiaries that had an index treat-and-release ED visit and a second ED visit within 7 days, did the beneficiary get admitted during the second ED visit	Admit from ED following hospital discharge For beneficiaries that that had an index hospitalization and a subsequent ED visit within 7 days, did the beneficiary get admitted during the second ED visit
Different orgs, no HIE: no. of pairs of organizations not on same HIE network (directional)	615	1787	669
Different orgs, HIE: no. of pairs of organizations on same HIE network (directional)	1243	3438	1578
Same org: no. of pairs where first and second organization are the same	1565	1665	1486
Beneficiary characteristics			
Number of unique beneficiaries	19 679	74 247	15 000
Number of observations	23 396	104 227	16 158
Average age of beneficiaries (SD)	77.94 (8.65)	77.32 (8.51)	76.25 (7.90)
Dual eligibles (%)[a]	27.78	29.80	22.54
Female (%)[b]	59.54	54.95	50.46
Race (%)[b]			
Asian	1.03	1.13	1.31
Black	9.59	11.99	10.82
Hispanic	1.80	1.82	1.65
North American Native	0.57	0.60	0.45
Other	0.99	1.20	1.27
Unknown	1.06	1.08	1.25
White	84.97	82.18	83.25
Relative frequency of 5 most common comorbidities (%)[c]			
Hypertension, uncomplicated	85.8%	85.9%	85.9%
Cardiac arrhythmias	53.0%	56.7%	64.4%
Fluid and electrolyte disorders	49.5%	53.5%	62.0%
	Chronic pulmonary disease 39.4%	Hypertension, complicated 44.4%	Hypertension, complicated 54.3%
	Hypertension, complicated 38.8%	Chronic pulmonary disease 43.3%	Chronic pulmonary disease 47.5%

[a] For at least 1 month in 2018.
[b] Categories from the Medicare enrollment file.
[c] From all diagnosis fields across inpatient, carrier, and outpatient files. Abbreviations: ED, emergency department; Org., organization; HIE, health information exchange.

classification random effects between beneficiaries and pairs, including beneficiary and hospital covariates.

Our first robustness test was a fixed effects specification using the receiving hospital as the fixed effect, so that the coefficient can be considered the within-hospital effect—that is, the average difference within each hospital between patients that had been treated at hospitals connected to the current hospital by HIE, those treated at hospitals not connected by HIE, and by those previously treated at the same hospital. Our second robustness test was a specification of the multilevel mixed models that substituted individual hospital covariates for pair-level covariates. Lastly, we replicated our main models on 2 subsets of beneficiaries who we hypothesized may disproportionately benefit from HIE: those with dementia and those with multi-morbidity. Details on these tests are in the Appendix.

Model results are reported as adjusted means by organizational relationship status with Bonferroni-adjusted treatment effects for differences between groups. All results were produced using Stata version 17.0. We follow the STROBE guidelines for observational studies.

Results

Sample sizes varied by outcome measure and timeframe. Sample sizes were: 58 105 (30-day) and 23 396 (7-day) for repeat imaging; 239 514 (30-day) and 104 227 (7-day) for discharge from ED to ED; and 39 702 (30-day) and 16 158 (7-day) for discharge from hospital to ED (Tables 1 and 2). Total pairs of organizations represented in these samples also varied by outcome. For the 30-day measure of discharge from ED to ED, 2470 distinct pairs of organizations were not connected by an HIE network; 4621 pairs of organizations were connected by an HIE network(s); and 1670 organizations fell into the "same" category (ie, beneficiary returned back to same organization for the second ED visit) (Table 1). Beneficiary demographics are also reported in Tables 1 and 2. On an average, the population was 75-80 years old with approximately 25%-30% dual-eligible and more than half female. There were high levels of comorbidity. The 7-day sample sizes were naturally smaller than the 30-day samples and in general comprised beneficiaries who were older and sicker. Sample characteristics further broken out by group—Different-No HIE, Different-HIE, and Same—are in Appendix Tables S3-8.

Unadjusted differences in outcomes revealed modest differences between the HIE and no HIE groups, with larger differences when compared to the Same reference group (Table 3). For 30-day repeat imaging, 32.16% of the sample had at least 1 repeat image for the Different-No HIE group compared to 28.97% for Different-HIE group. The Same group was 25.66%. Equivalent numbers for the 7-day sample were: 28.35%, 25.95%, and 23.25%. For our measure of beneficiaries admitted from the ED following a treat-and-release ED visit, levels were 54.85%, 50.42%, and 31.35%, respectively for the 30-day measure and 57.39%, 50.53%, and 25.97%, respectively for the 7-day measure. Lastly, for our measure of beneficiaries admitted from the ED following a hospital discharge, levels were 49.10%, 55.40%, and 10.47%, respectively for the 30-day measure and 45.40%, 53.59%, and 12.06%, respectively for the 7-day measure.

In adjusted mixed effects models, these results largely persisted. For 30-day repeat imaging, the difference between Different-HIE and Different-No HIE was not statistically significant for 30- or 7-day measures. Compared to the Same reference group: for Different-HIE, there was a 4.02 pp lower likelihood of repeat imaging (95% CI, −5.79 to −2.25, with adjusted means of 29.58% vs 25.56% representing a relative reduction of 13.59%) and Different-No HIE, there was a 6.31 percentage point lower likelihood (95% CI, −8.98 to −3.65, with adjusted means of 31.87% vs 25.56% representing a relative reduction of 19.80%) (adjusted means in Figure 1; treatment effects in Appendix Table S9). Results were similar for our 7-day measure.

For likelihood of hospitalization during the second ED visit following an initial treat-and-release ED visit within 30 days, unlike the prior measure, HIE connectivity between different EDs was associated with a 1.83 pp lower likelihood of admission (95% CI, −3.44 to −0.21, with adjusted means of 48.73% vs 46.91% representing a relative reduction of 3.76%) versus Different-No HIE. Results were similar for our 7-day measure. However, the lowest level of admission occurred for Same: compared to Different-HIE, there was a 13.77 pp lower likelihood of admission (95% CI, −14.92 to −12.6, with adjusted means of 46.91% vs 33.14% representing a relative reduction of 29.35%) and compared to Different-No HIE, the percentage point difference was even greater (15.59; 95% CI, −17.12 to −14.06, with adjusted means of 48.73% vs 33.14% representing a relative reduction of 31.99%) (Figure 2; Appendix Table S9).

Our last measure—the likelihood of hospitalization during an ED within 30 days following an initial hospitalization—

Table 3. ED utilization outcomes by hospital relationship status.

	30 days >65	7 days >65
Repeat imaging[a]		
% with any repeat imaging (same modality, same body region) during the second ED visit	%	%
Different orgs, No HIE	32.16	28.35
Different orgs, HIE	28.97	25.95
Same org	25.66	23.25
Admit from ED following ED visit[a]		
% admitted during the second ED visit		
Different orgs, No HIE	54.85	57.39
Different orgs, HIE	50.42	50.53
Same org	31.35	25.97
Admit from ED following hospital discharge[b]		
% admitted during the second ED visit		
Different orgs, No HIE	49.10 (1365)	45.40
Different orgs, HIE	55.40	53.59
Same org	10.47	12.06

[a] 30-day/7-day refer to the time periods in which the 2 ED visits occurred; relationship between first and second ED defined as: "Different, No HIE"—the 2 EDs are different (not part of same organization or health system) and they do not participate in the same health information exchange network(s); "Different, HIE"—the 2 EDs are different (not part of same organization or health system) and they do participate in the same health information exchange network(s); and "Same"—the beneficiary returned to the same organization.

[b] 30-day/7-day refer to the time periods in which the 2 utilization events (hospitalization followed by an ED visit) occurred; Relationship between Hospital and Second ED defined as: "Different, No HIE"—the 2 organizations are different (not part of same organization or health system) and they do not participate in the same health information exchange network(s); "Different, HIE"—the 2 organizations are different (not part of same organization or health system) and they do participate in the same health information exchange network(s); and "Same"—the beneficiary returned to the same organization. Abbreviations: ED, emergency department; Org., organization; HIE, health information exchange.

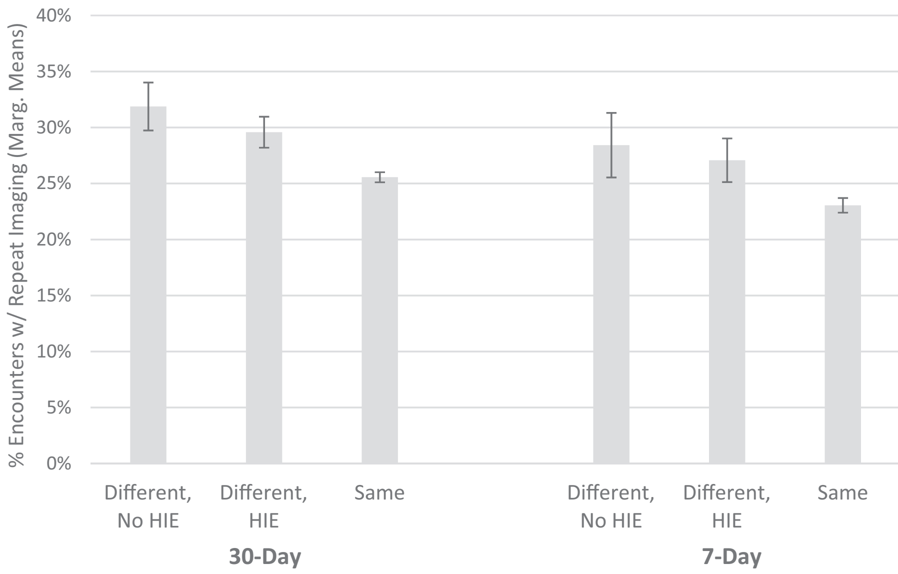

Figure 1. Adjusted means: percent of encounters with repeat imaging by relationship between first and second ED. 30-day/7-day refer to the time periods in which the 2 ED visits occurred; relationship between first and second ED defined as: "Different, No HIE"—the 2 EDs are different (not part of same organization or health system) and they do not participate in the same health information exchange network(s); "Different, HIE"—the 2 EDs are different (not part of same organization or health system) and they do participate in the same health information exchange network(s); and "Same"—the beneficiary returned to the same organization. Marginal effects reported in Appendix Table S9. Abbreviations: ED, emergency department; HIE, health information exchange.

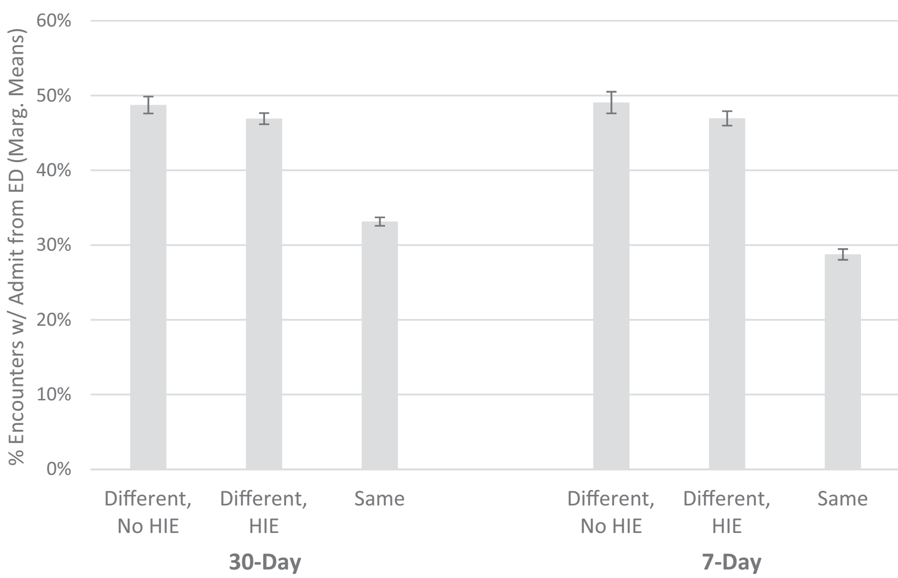

Figure 2. Adjusted means: percent of encounters with admit from ED following treat-and-release ED visit by relationship between first and second ED. 30-day/7-day refer to the time periods in which the 2 ED visits occurred; relationship between first and second ED defined as: "Different, No HIE"—the 2 EDs are different (not part of same organization or health system) and they do not participate in the same health information exchange network(s); "Different, HIE"—the 2 EDs are different (not part of same organization or health system) and they do participate in the same health information exchange network(s); and "Same"—the beneficiary returned to the same organization. Marginal effects reported in Appendix Table S9. Abbreviations: ED, emergency department; HIE, health information exchange.

showed a somewhat different pattern of results. Different-HIE had a 2.78 percentage point higher likelihood of hospitalization compared to Different-No HIE (95% CI, 0.48-5.08, with adjusted means of 50.47% vs 47.69% representing a relative increase of 5.83%). Again, results were similar for our 7-day measure and the lowest level of admission occurred for Same: compared to Different-HIE, there was a 40.27 pp lower likelihood of admission (95% CI, −42.03 to −38.50, with adjusted means of 50.47% vs 10.20% representing a relative reduction of 79.79%) and compared to Different-No HIE, the percentage point difference was 37.49 (95% CI, −39.75 to −35.23, with adjusted means of 47.69% vs 10.20% representing a relative reduction of 78.61%) (Figure 3).

In robustness tests, our fixed effects models had similar results. However, for both 30- and 7-day results, the higher likelihood of hospital admission following hospital discharge for Different-HIE versus Different-No HIE was no longer statistically significant (30-day: 1.53; 95% CI, −1.23 to 4.29; 7-

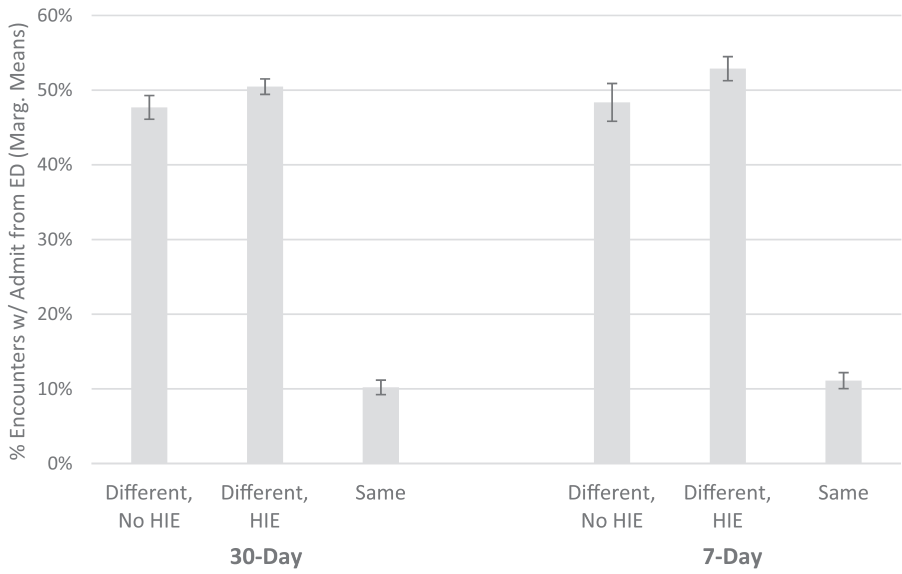

Figure 3. Adjusted means: percent of encounters with admit from ED following hospital discharge by relationship between hospital and second ED. 30-day/7-day refer to the time periods in which the 2 utilization events (hospitalization followed by an ED visit) occurred; relationship between hospital and second ED defined as: "Different, No HIE"—the 2 organizations are different (not part of same organization or health system) and they do not participate in the same health information exchange network(s); "Different, HIE"—the 2 organizations are different (not part of same organization or health system) and they do participate in the same health information exchange network(s); and "Same"—the beneficiary returned to the same organization. Marginal effects reported in Appendix Table S9. Abbreviations: ED, emergency department; HIE, health information exchange.

day: 1.57; 95% CI, −3.19 to 6.33) (Appendix Table S9). When we substituted individual hospital covariates for pair-level covariates, some results were no longer statistically significant and 30-day repeat imaging became statistically significant (−3.8; 95% CI, −6.7 to 0.9); however, all coefficients were similar in direction and magnitude (Appendix Table S10). Lastly, we found no consistent evidence of greater benefits from HIE for those with dementia and those with multi-morbidity.

Discussion

Our study offers robust national evidence on the association between electronic connectivity and utilization outcomes in the ED setting. We compare when beneficiaries receive care from different EDs that are not connected by HIE and those that are connected by HIEs, with return to the same ED as a reference group. We found that, among those going to different organizations, HIE was not associated with lower levels of repeat imaging. We also found that, following an initial treat-and-release ED visit, beneficiaries treated at a different ED were substantially less likely to be hospitalized during the second ED visit if the 2 organizations were connected via HIE than if they were not, but they were also more likely to be hospitalized during a subsequent ED visit after a hospital discharge. However, for all 3 outcomes, the reference group of those returning to the same organization was substantially better, compared to both different ED groups. While better outcomes are undoubtedly due in part to differences in ED groups beyond what we were able to adjust for (eg, urgency and complexity), given that all EDs treat many urgent and complex cases, it suggests that other factors explain the gap.

Beyond patient differences, there are many reasons why returning to the same ED could result in lower utilization as compared to going to a different ED. Given the large magnitude effect sizes, it is likely not solely about better access to prior records. Returning to the same organization also has the advantages of an established patient relationship (ie, the care team may be familiar with the patient and their broader social circumstances); there may be existing protocols in place for return visits for "frequent flyers"; and there could be resources such as case workers that have already identified community resources available to the patient based on previous visits.[24,25] In addition, organizations have incentives to avoid readmissions under the Hospital Readmissions Reduction Program and other accountable care and risk-based models.[26] Thus, they likely have built processes for how to handle patients that have returned to the ED to avoid readmissions. Our study is the first that we know of that compares this group to those with fragmented ED visits and suggests a substantial opportunity to reduce utilization by determining how different organizations can coordinate (via HIE or other mechanisms) to deliver similar results. In so doing, we reinforce parallel work focused on interhospital fragmentation among inpatients.[1] Future work that more rigorously adjusts for patient differences would help clarify the specific magnitude of opportunity.

Our results comparing beneficiaries going to different EDs with and without HIE do not face this same limitation and therefore more robustly reflect differences likely attributable to HIE. While we did not find a relationship between HIE and repeat imaging, several prior studies have found such an association and there is strong motivation to avoid repeat imaging due to associated patient harm and cost.[4] For example, one prior study found a decrease in repeat imaging of 8.7 percentage points among EDs that used HIE[27]; another found substantially lower odds of repeat imaging among headache patients[28]; one found decreased imaging of 1.2 percentage points[27]; while a fourth showed no direct association between HIE use and imaging.[15] Given that our results are more recent, the cumulative evidence does not reflect larger or more consistent benefits from HIE over time. We suspect that this is because the majority of prior studies focus on a small number of mature HIE networks, which likely have better uptake and impact. Thus, in our current national-scale study, we are capturing a more generalizable result in which there is substantial variability in the impact of HIE on repeat imaging, likely driven by the fact that HIE networks vary in the extent of breadth of data included, workflow integration, and even awareness among frontline clinicians.[4,6,29]

However, we did find significant associations for our hospital utilization measures, which suggest a nuanced set of mechanisms. We suspect that HIE helps avoid admissions for patients who are less complex (those with a prior treat-and-release ED visit) but increases likelihood of admission for patients who are more complex (those with a prior hospitalization). Specifically, in the former case, when patients are less complex, having access to the prior ED record may help the clinician more confidently decide that the patient is stable enough to discharge home. In the latter case, having access to the prior hospitalization record may convey additional clinical complexity and push the clinician to decide to re-hospitalize the patient. In this case, the value of HIE may not be in reducing utilization but in increasing appropriate utilization, a hypothesis that will be important to test in future work. However, we do note that the relationship between HIE use and likelihood of admission following a hospitalization is not differentiable from zero in the fixed-effects specification.[30] This indicates that there may be systematic differences between the hospitals where the second ED visit occurs that is correlated with likelihood of HIE status and is addressed by generating within-hospital estimates using the fixed-effects specification but is not addressed by the hospital covariates included in the random effects model.

Overall, our results add important evidence on the need for continued effort to realize the full potential benefit of HIE and in particular, identify the underlying mechanisms. While it is not reasonable to expect that different EDs with HIE have outcomes equivalent to the Same reference group, the substantial difference in outcomes between patients treated at a different ED connected by HIE and patients returning to the same ED suggests that new insights may emerge from understanding the mechanisms driving that differential performance to inform policy and practice strategies. Some mechanisms are addressable by policy and technology performance, such as if clinicians are not aware that information exchanged via HIE is available or not usable (as has been shown in prior work).[4] Other mechanisms are likely not addressable. For example, even when a patient has extensive data from prior encounters, when they return to the same ED clinicians are likely more familiar with how information is organized and labeled within their home system, making it easier to navigate to the subset of information that is relevant to the given clinical decision. While the underlying mechanisms need further investigation, policymakers should consider stronger actions to drive improved usability as well as more effective use of HIE capabilities, such that distinct organizations operate in a more coordinated way.

Our study has important limitations. First, our study uses 2018 data, the most recent year available at the time we started our study given the lag in Medicare claims. HIE networks have likely matured in the intervening years, suggesting that our estimates of impact may be conservative and arguing for repeating this study in the post-COVID period when claims are available. In addition, we included heterogenous types of HIE networks and in future work it will be important to assess whether associations differ by type of network. Second, we lacked complete HIE participation data from all US hospitals and therefore limited our sample to pairs for which we knew the HIE participation status of both hospitals. While this may limit the generalizability of our results to hospitals that reported data to Definitive and/or responded to the AHA IT Supplement, both sources have high response rates, resulting in the largest sample of HIE participation data at the hospital-pair level that can be constructed using secondary data. Third, we do not directly observe the level of investment in HIE capabilities in the ED setting. That is, even when a hospital reports that they participate in a given network, they may not have made frontline ED clinicians aware of how to access the records via the HIE network or designed seamless integration, making the records easy to access. Thus, again, our results could reflect a conservative estimate of the full potential impact of HIE. However, we intentionally did not attempt to rely on *use of HIE* as our exposure given the risk of bias if HIE use is related to patient status. Lastly, as mentioned above, our beneficiary-level controls were likely insufficient to fully adjust for patient differences in the same versus different ED groups.

Conclusion

Our study offers the first national-scale evidence of the relationship between HIE and ED outcomes in the context of fragmented ED encounters using the best-available measures of HIE connectivity from multiple sources of secondary data. By including as a reference group instances in which beneficiaries returned to the same organization, it reveals that, even when HIE is associated with lower utilization (for our measure of hospital admission following a treat-and-release ED visit), returning to the same organization is associated with dramatically lower levels. Further, our finding that HIE is associated with higher utilization (for our measure of hospital admission following hospital discharge) suggests a nuanced set of mechanisms through which HIE may impact utilization. Our findings overall suggest the need for stronger policies to incentivize HIE use that facilitates optimal utilization decisions and complementary efforts to overcome the impact of care fragmentation.

Author contributions

All authors contributed to the study concept and design and interpretation of results, as well as drafting and revising the manuscript. A.L. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Supplementary material

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

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Conflicts of interest

JAM is on the Board and holds shares in Opala.

Data availability

The data underlying this article cannot be shared publicly due to the terms of data use agreements with CMS, Definitive, and AHA.

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