

# Impact of Electronic Information Exchange on Repeat Imaging During 30-Day Readmissions Among Medicare Beneficiaries

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As US health care costs continue to rise,<sup>1</sup> efforts to decrease low-value care remain at the forefront for policy makers, payers, clinicians, and patients. Repeat imaging is a common type of low-value care; in 2007, 20% of surveyed patients reported undergoing duplicate imaging procedures.<sup>2</sup> As of 2009, radiology procedures were estimated to cost \$100 billion per year in the US,<sup>3</sup> and 20% to 25% of these tests represent inappropriate or low-value care.<sup>4,5</sup>

One factor that may increase the potential for repeat imaging is lack of access to a patient's previous imaging studies,<sup>6</sup> such as during a fragmented readmission, which is when a patient has a readmission to a different hospital than the one from which they were previously discharged. Fragmented readmissions occur in up to 25% of readmissions and are associated with higher rates of health care use, including longer lengths of stay and more readmissions.<sup>7</sup>

Health information exchanges (HIEs)—electronic systems for accessing health data across settings of care—have been proposed as a solution to decrease duplicate imaging.<sup>8</sup> HIEs have been widely adopted,<sup>9</sup> but previous investigations regarding the association between electronic health information sharing and repeat imaging have shown mixed results. A 2012 study found 40% to 70% greater odds of imaging orders by physicians with access to previous imaging results,<sup>10</sup> whereas another study examining HIE and repeat imaging found nearly the opposite: that HIE use was associated with a 25% reduction in repeat imaging.<sup>11</sup>

Older adults and particularly individuals with diseases such as Alzheimer disease (AD) that may affect their ability to relay critical points in their prior medical history may be at higher risk of low-value care, including repeat imaging during fragmented readmissions. Because most imaging procedures are performed in older patients<sup>2</sup> and the rate of imaging use increased by approximately 5% per year between 2014 and 2016 among older adults,<sup>12</sup> it is crucial to understand the contexts in which duplicative imaging occurs in this population.

In this study, we examined Medicare data from 2018 to investigate the association between fragmented readmissions as well as types of information shared in fragmented 30-day readmissions and

## ABSTRACT

**OBJECTIVES:** We examined the association between electronic health information sharing and repeat imaging in readmissions among older adults with and without Alzheimer disease (AD).

**STUDY DESIGN:** Cohort study using national Medicare data.

**METHODS:** Among Medicare beneficiaries with 30-day readmissions in 2018, we examined repeat imaging on the same body system during the readmission. This was evaluated between fragmented and nonfragmented (same-hospital) readmissions and across categories of electronic information sharing via health information exchanges (HIEs) in fragmented readmissions: admission and readmission hospitals share the same HIE, admission and readmission hospitals participate in different HIEs, one or both do not participate in HIE, or HIE data missing. This relationship was evaluated using unadjusted and adjusted logistic regression.

**RESULTS:** Overall, 14.3% of beneficiaries experienced repeat imaging during their readmission. Compared with nonfragmented readmissions, fragmented readmissions were associated with 5% higher odds of repeat imaging on the same body system in older adults without AD. This was not mitigated by the presence of electronic information sharing: Fragmented readmissions to hospitals that shared an HIE had 6% higher odds of repeat imaging (adjusted OR, 1.06; 95% CI, 1.00-1.13). There was no difference seen in the odds of repeat imaging for older adults with AD.

**CONCLUSIONS:** Despite substantial investment, HIEs as currently deployed and used are not associated with decreased odds of repeat imaging in readmissions.

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the odds of duplicate radiology exams among beneficiaries with and without AD.

## METHODS

### Data Sources

Hospital admissions and imaging studies were identified in the 2018 Medicare Provider Analysis and Review (MedPAR) file for fee-for-service beneficiaries. Additional imaging studies were obtained from the 2018 Medicare Carrier File. Patient demographics and clinical characteristics were found in the Medicare Master Beneficiary Summary File and its Chronic Conditions segment. Hospital information was obtained from the 2018 American Hospital Association (AHA) Annual Survey and the 2017-2018 AHA Annual Survey Information Technology Supplement (henceforth, IT Supplement; completed in 2018-2019). The AHA Annual Survey is a voluntary survey of hospitals and health care systems.<sup>13</sup> The IT Supplement is a supplemental survey conducted with the AHA Annual Survey.<sup>14</sup>

### Patients

This analysis included Medicare beneficiaries who had a hospital admission for select Hospital Readmissions Reduction Program diagnoses (acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, pneumonia)<sup>15</sup> or common causes of hospitalization among older adults, particularly those with AD (dehydration, syncope, urinary tract infection, behavioral issues) (*International Statistical Classification of Diseases, Tenth Revision [ICD-10]* codes in [eAppendix A](#) [eAppendices available at [ajmc.com](#)]).<sup>16</sup> All index admissions in the analytic sample were for one of these reasons, but readmissions could be for any reason. Beneficiaries with and without AD were included in the analysis.

Beneficiaries were excluded if they did not have any readmissions within 30 days of their index admission, if their beneficiary identifier was missing, or if the admissions/readmissions represented hospital-to-hospital transfers. Admissions and 30-day readmissions were transformed into admission-readmission pairs; a beneficiary could have multiple admission-readmission pairs if they had more than 2 admissions in the data set. The final sample included only admission-readmission pairs in which an imaging study was performed during the index admission.

### Main Exposure: Level of Health Information Sharing Between Admission and Readmission Hospitals

Fragmented readmissions were defined as an admission and subsequent readmission to different hospitals. Information sharing was defined as the category of health care information sharing at the hospital level based on the data available in the AHA Annual Survey and IT Supplement. The reference category was nonfragmented/same-hospital readmissions, which is when the index admission and readmission were to the same hospital. All fragmented readmissions

## TAKEAWAY POINTS

We examined the association between repeat imaging and health information exchange (HIE) during fragmented readmissions in older adults with and without Alzheimer disease (AD).

- ▶ Fragmented readmissions were associated with 5% higher odds of repeat imaging in older adults without AD; this did not decrease when the admission and readmission hospitals shared an HIE.
- ▶ HIE was not found to decrease the odds of repeat imaging in this population at high risk for low-value care.
- ▶ Policy makers should continue to incentivize robust information sharing, including sharing of radiology images, and encourage HIE use at the point of care.

were divided into 4 subcategories based on hospital-level HIE participation: same HIE pairs, where both the admission and readmission hospital participated in the same HIE; different HIE pairs, where both hospitals participated in HIE, but the HIEs were different; no HIE, where 1 or both hospitals indicated that they do not participate in HIE; or HIE missing, where HIE status was missing due to nonresponse to the IT Supplement or the HIE question.

HIE participation was determined by the response to the question: "Please indicate your level of participation in a state, regional, and/or local [HIE] or health information organization [HIO]" on the IT Supplement. Answers could be "do not know," "HIE/HIO is not operational in my area," "HIE/HIO is operational...we are not participating," or "HIE/HIO is operational...we are participating." If the hospital answered that it was participating in HIE on an IT Supplement in 2017 or 2018, it was classified as having HIE in this analysis. If a hospital had different or missing answers across years of data, we used the answer reflecting its highest level of information sharing. To determine which HIE a hospital participated in, we examined answers to the questions: "Which of the following national health information networks does your hospital participate in?" Potential responses included "your [electronic health record (EHR)] vendor's network" and "other," which offered free-text response options. If a hospital responded "your EHR vendor's network," we examined potential free-text response options as well as its answer to the survey question regarding the primary inpatient EHR. Because a beneficiary could have multiple admission-readmission pairs in this analysis, they could have pairs in more than 1 category of information sharing.

### Main Outcome: Repeat Imaging of the Same Body System

The main outcome for this study was repeat imaging of the same body system performed during the 30-day readmission. Imaging was identified via *ICD-10* procedure codes in the MedPAR file and by Berenson-Eggers Type of Service (BETOS) codes in the Carrier file.<sup>17</sup> Each hospitalization could have up to 25 *ICD-10* procedure codes listed. The anatomical region examined by the imaging procedure is identified by the second character of the *ICD-10* procedure code; 31 potential anatomic regions are delineated within *ICD-10*.<sup>18</sup> The mapping of BETOS codes to *ICD-10* anatomic regions can be found in [eAppendix B](#).

Repeat imaging on the same body system occurred if an imaging procedure/BETOS code in the readmission had the same body system as an imaging procedure/BETOS code in the index admission. All outcomes were agnostic to imaging modality used; for example, a chest CT and chest x-ray would be considered repeat imaging on the same body system. Additionally, we did not include the number of repeat imaging studies performed as part of the primary outcome.

### Analytic Approach

Univariate statistics were used to compare characteristics of beneficiaries with admission-readmission pairs across the categories of information sharing (nonfragmented/same hospital [reference], same HIE, different HIE, no HIE, missing HIE). The demographic characteristics examined were beneficiary age, sex, and race. The clinical characteristics were the Charlson Comorbidity Index (CCI) score<sup>19</sup> and the diagnosis related group (DRG) code of the readmission. The readmission hospital characteristics included were urban/rural status (metropolitan, micropolitan, and rural), number of hospital beds (< 200, 200-399, ≥ 400), hospital ownership (public, for-profit, government, and church), teaching status, and type of hospital. Urban/rural status was identified via the rural-urban commuting area code of the hospital.<sup>20</sup> Hospitals were labeled teaching hospitals if they reported programs accredited by the Accreditation Council for Graduate Medical Education, the American Osteopathic Association, or the Council of Teaching Hospitals, or if they were affiliated with a medical school. Hospitals were classified as either general medical/surgical or “other,” which included specialty hospitals.<sup>13</sup>

We used unadjusted and adjusted logistic regression models to evaluate the association between fragmented readmissions and repeat imaging on the same body system and then between HIE category and repeat imaging on the same body system. All models included readmission hospital fixed effects and robust SEs clustered at the hospital level; fixed effects were included to account for potential unobserved differences in hospital-level practice patterns regarding imaging studies. The reference group was nonfragmented/same-hospital readmission pairs.

Models were separately adjusted for demographic/clinical (age, sex, race, CCI, DRG) and readmission hospital characteristics. A final model that included all covariates was also created. Older adults with and without AD were included; regression results were stratified a priori by AD diagnosis. If a patient was listed as ever having AD in the Chronic Conditions segment, they were considered to have AD for this analysis.

### Sensitivity Analysis

To assess the robustness of our estimates, we performed several sensitivity analyses. First, we stratified the analysis by the number of pairs present per patient (1 or ≥ 2) to determine whether HIE had a different effect on patients with multiple readmissions. We also examined the association between HIE and repeat imaging on the same body system among beneficiaries in the sample who had an MRI during their index admission. MRIs were identified by a value

greater than 0 in the “MRI\_CHRG” variable of the index admission. This was done to measure whether health information sharing had a differential impact on more advanced or costly radiology procedures as previously described in the literature.<sup>10</sup> Next, we examined only admission-readmission pairs with repeat imaging on the same body system and examined whether HIE status was associated with more than 1 instance of repeat imaging during the readmission vs a single instance of repeat imaging during the readmission. This was done to assess whether HIE was associated with the volume of repeat imaging. Finally, we used advanced imaging on the same body system as the outcome, defined by the presence of an ICD-10 or BETOS code for CT, MRI, and/or ultrasound during the admission and/or readmission. This was done to assess whether there was a different association between HIE status and repeat imaging on the same body system when first-line imaging, such as x-rays, was not considered. Because of the small sample size, hospital fixed effects were not included in the final sensitivity analysis.

We conducted analyses using SAS 9.4 (SAS Institute) and Stata 17 (StataCorp LLC). This study was approved by the institutional review board of Emory University School of Medicine and funded by the National Institute on Aging at the National Institutes of Health.

## RESULTS

The analytic sample included 275,860 admission-readmission pairs representing 269,348 unique patients admitted to 3436 hospitals; 13.2% of pairs had AD. Full details of the sample development can be found in [Figure 1](#).

The majority (66.0%; n = 182,083) of pairs were nonfragmented/same-hospital readmissions ([Table](#)); 4.6% (n = 12,641) were to hospitals that shared the same HIE, 7.3% (n = 20,006) were to hospitals with different HIEs, 5.9% (n = 16,195) of admission-readmission pairs had 1 or more hospitals that did not participate in HIE, and 16.3% (n = 44,933) of pairs had missing HIE data. Same-HIE readmissions had the lowest proportion of female beneficiaries (51.4% vs 52.5%-54.6%;  $P < .0001$ ) and the highest proportion of beneficiaries living in urban areas (95.0% vs 82.4%-91.1%;  $P < .0001$ ). Repeat imaging was most common in same-HIE readmissions (15.9%) and least common in nonfragmented readmissions (14.0%).

Fragmented readmissions were associated with a 5% increase in the odds of repeat imaging on the same body system for beneficiaries without AD in fully adjusted models (adjusted OR [AOR], 1.05; 95% CI, 1.02-1.08). There was no difference in the odds of repeat imaging on the same body system in fragmented readmissions for beneficiaries with AD (AOR, 0.89; 95% CI, 0.89-1.08) ([Figure 2](#) and [eAppendix D](#)).

In fully adjusted models for beneficiaries without AD, same-HIE readmissions had a 6% increase in the odds of repeat imaging on the same body system (AOR, 1.06; 95% CI, 1.00-1.13), different-HIE readmissions had an 8% increase (AOR, 1.08; 95% CI, 1.03-1.13), and no- or missing-HIE readmissions had no difference (no HIE: AOR, 1.05; 95% CI, 0.99-1.10; missing HIE: AOR, 1.03; 95% CI, 0.96-1.11) ([Figure 2](#) and [eAppendix E](#)). Among beneficiaries with AD, there

was no significant difference between any category of information sharing and the odds of repeat imaging when comparing fragmented readmissions with nonfragmented readmissions.

Results for the sensitivity analysis on beneficiaries with only 1 admission-readmission pair in the data set were similar to the primary analysis (eAppendix F). There was no difference in the odds of repeat imaging on the same body system across any category among beneficiaries with 2 or more admission-readmission pairs or among beneficiaries who had an MRI during their index admission (eAppendices F and G). Beneficiaries without AD with same-HIE readmissions had 34% higher odds of having more than 1 instance of repeat imaging on the same body system compared with those with a single repeat image (AOR, 1.34; 95% CI, 1.02-1.75); there was no difference in the odds of having more than 1 instance of repeat imaging vs only 1 instance of repeat imaging for all other HIE statuses and for beneficiaries with AD (eAppendix H). When repeat imaging on the same body system was limited to admissions and/or readmissions with advanced imaging, same-HIE readmission was associated with 58% higher odds of repeat imaging on the same body system among older adults without AD when hospitals shared an HIE (AOR, 1.58; 95% CI, 1.00-2.49). Admission-readmission pairs for which no HIE was available were associated with 76% higher odds of repeat imaging on the same body system among beneficiaries without AD (AOR, 1.76; 95% CI, 1.20-2.58) (eAppendix I).

## DISCUSSION

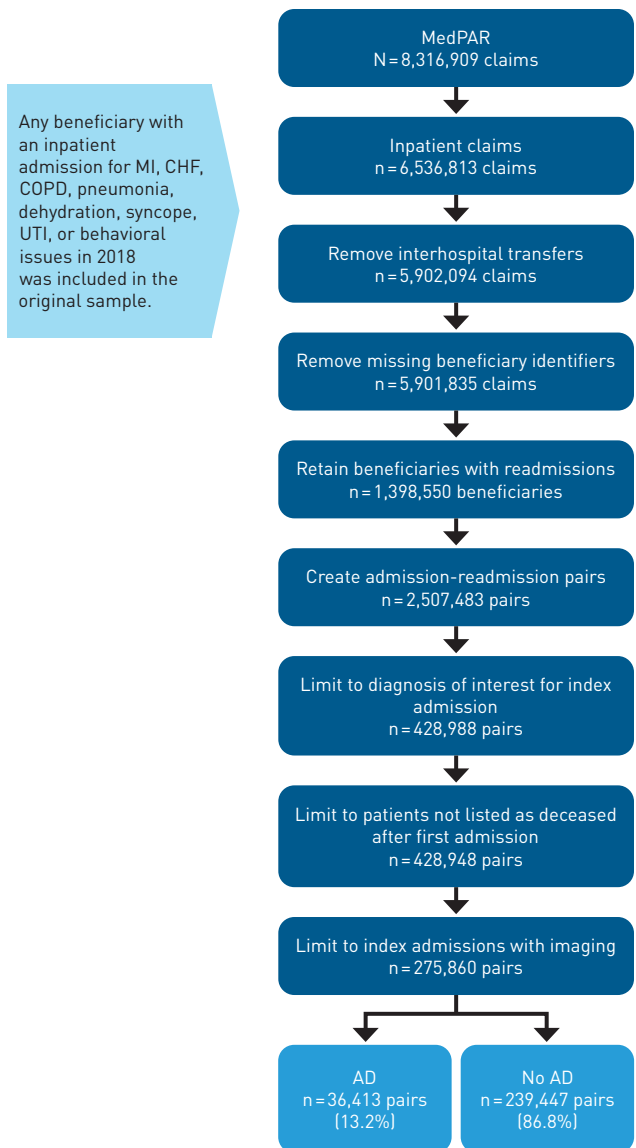
In this study, we found an increase in the odds of repeat imaging among beneficiaries without AD during a fragmented readmission when electronic health information sharing was available. However, contrary to our hypothesis, we found no difference in the odds of repeat imaging during readmissions for beneficiaries with AD regardless of whether the readmission was fragmented or health information sharing was available.

For older adults without AD, these results suggest that the availability of information sharing between hospitals is not enough to mitigate the increased odds of repeat imaging associated with fragmented care. These findings are in line with previous work that found increased odds of repeat imaging when providers had access to a patient's prior images.<sup>10</sup> Possible reasons for this association could include that it is easier to order a test instead of searching through an HIE for past results<sup>10</sup> or that the information the clinician is seeking is not available in the HIE. In previous studies, lack of necessary information was a top reason that providers did not more frequently access HIE.<sup>21,22</sup> This reflects an important limitation of this and all studies in which "HIE presence" is substituted for "HIE use by providers."<sup>23-26</sup>

### Limitations

We were not able to detect differences in the odds of repeat imaging among older adults with AD based on fragmented readmission status or the presence of HIE. Although Medicare beneficiaries

**FIGURE 1.** Development of Analytic Sample, 2018 Medicare Data



AD, Alzheimer disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; MedPAR, Medicare Provider Analysis and Review; MI, myocardial infarction; UTI, urinary tract infection.

with AD represented a significantly smaller segment of the overall study population, our results may align with those of studies suggesting that low-value care is prevalent in dementia,<sup>27</sup> leading to similar levels of repeat imaging observed across settings of care with different types of information sharing. Studies, including mixed-methods studies, could further evaluate the potential factors influencing these findings.

There are other limitations of this study. First, responses to the AHA IT Supplement may introduce differential misclassification bias into our exposure categories, as hospitals with lower health IT

**TABLE.** Demographics and Clinical Information of Admission-Readmission Pairs With Imaging During Their Index Admission, 2018

Characteristic	Total (n = 275,860)	Nonfragmented/ same hospital (n = 182,085)	Same HIE (n = 12,641)	Different HIE (n = 20,006)	No HIE (n = 16,195)	Missing HIE (n = 44,933)	P
Age in years, mean (SD)	78.6 (9.0)	78.9 (9.0)	77.9 (8.8)	77.9 (8.7)	77.9 (8.7)	78.4 (8.9)	<.0001
Sex							<.0001
Female	54.0%	54.6%	51.4%	52.7%	52.5%	53.9%	
Male	46.0%	45.4%	48.6%	47.3%	47.5%	46.1%	
Race							<.0001
White	81.9%	83.1%	79.6%	77.9%	79.9%	80.2%	
Black	12.4%	11.7%	14.9%	15.8%	14.1%	12.6%	
Other	5.7%	5.2%	5.5%	6.3%	6.0%	7.2%	
Alzheimer disease							.180
Yes	13.2%	13.3%	12.6%	13.0%	13.0%	13.1%	
Charlson Comorbidity Index score, mean (SD)	3.9 (2.4)	4.0 (2.4)	4.0 (2.4)	3.8 (2.4)	3.8 (2.4)	3.8 (2.4)	<.0001
Urban/rural status							<.0001
Metropolitan	87.3%	87.4%	95.0%	91.1%	88.7%	82.4%	
Micropolitan	9.4%	9.8%	3.5%	6.5%	8.4%	11.0%	
Rural	3.3%	2.7%	1.5%	2.4%	2.9%	6.6%	
Number of beds							<.0001
< 200	30.6%	28.4%	25.6%	28.4%	30.6%	42.1%	
200-399	35.9%	36.6%	32.3%	33.0%	32.0%	37.0%	
≥ 400	33.5%	35.1%	42.1%	38.5%	37.3%	20.9%	
Hospital ownership							<.0001
Government	10.3%	10.6%	8.5%	10.2%	13.1%	8.6%	
Religious	12.6%	12.4%	12.9%	12.3%	11.9%	13.3%	
Nonprofit	60.3%	63.8%	67.0%	59.9%	56.2%	45.7%	
For-profit	16.8%	13.1%	11.6%	17.6%	18.8%	32.3%	
Hospital type							<.0001
General medical/surgical	98.8%	99.8%	96.7%	95.7%	96.0%	97.5%	
Other	1.2%	0.2%	3.3%	4.2%	4.0%	2.5%	
Teaching hospital	71.5%	72.8%	78.5%	74.9%	71.1%	62.7%	<.0001
Repeat imaging on the same body system	14.3%	14.0%	15.9%	15.8%	15.2%	14.4%	<.0001

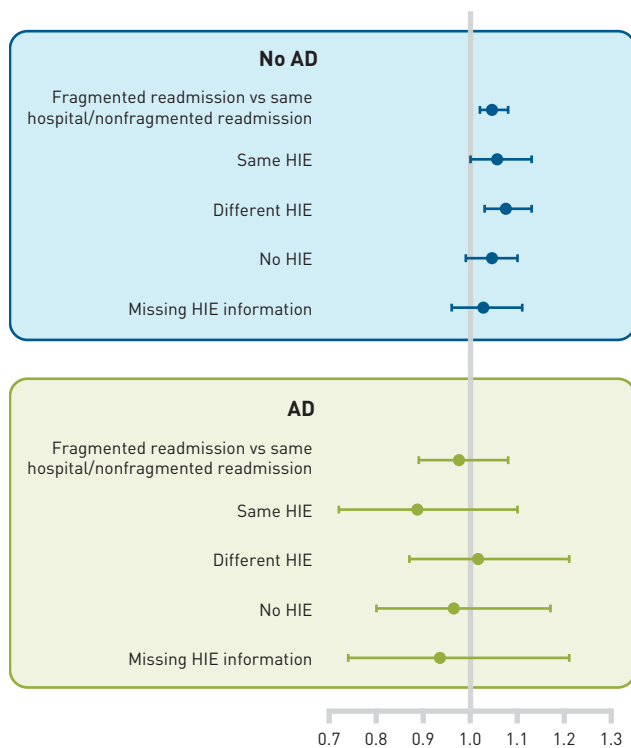
HIE, health information exchange.

capabilities may be less likely to respond to this survey. We attempted to mitigate this limitation through our sensitivity analyses, which did not alter the results. In the future, studies should aim to directly measure HIE use rather than relying on the proxy of “HIE available.” Second, we did not include imaging type as part of our outcome measure, and we must acknowledge that not all repeat imaging is wasteful. If a patient arrives with stroke symptoms, they should get imaging no matter when previous imaging was done or what it showed. This may be particularly pertinent to older adults with AD, in whom many acute illnesses present with altered mental status, motivating clinicians to obtain imaging to further investigate. Third, our approach might mask appropriate repeat imaging informed by results of outside radiology procedures—for example, a chest CT ordered during a readmission to evaluate findings from a previous chest x-ray reviewed via HIE. Teasing apart appropriate vs inappropriate repeat imaging will be important in future work.

## CONCLUSIONS

If reducing repeat imaging procedures is a goal to decrease low-value care, these results demonstrate that for most older adults, HIEs do not appear to be contributing to that goal. It is important to note that we do not have data on what types of radiology information (reports, imaging, or other pieces of data) are shared via these HIEs. The technology to share radiology images exists; radiology image file types are standardized,<sup>28</sup> so images are interoperable across platforms. However, images often remain siloed within hospitals and health systems. Sharing radiology images nationwide and making them easy to access could have tangible benefits for patients and the health care system. Future work should also seek to understand how providers perceive information from outside sources. Perhaps a repeat imaging test is ordered because the provider does not trust the interpretation from another hospital. This is also a situation

**FIGURE 2.** Association Between Fragmented Readmissions, Electronic Information Sharing, and Repeat Imaging, Stratified by AD Diagnosis, 2018 Medicare Beneficiaries\*



AD, Alzheimer disease; HIE, health information exchange.  
 \*ORs for repeat imaging during a 30-day readmission in fragmented readmissions compared with nonfragmented/same-hospital readmissions and in fragmented readmissions with different categories of information sharing [same HIE, different HIE, no HIE, missing HIE information] compared with nonfragmented readmissions, stratified by AD status. Models are adjusted for patient age, sex, race, Charlson Comorbidity Index score, diagnosis related group of the readmission, readmission hospital urban/rural status, size, ownership, type (general medical/surgical vs other), and teaching status. Readmission hospital fixed effects and robust SEs clustered at the hospital level were used.

in which having access to the images themselves could be beneficial.<sup>29,30</sup> Although health care systems have the tools to address this type of low-value care, they may have limited incentives to correct it when they are reimbursed on a fee-for-service basis and not penalized for repeat imaging. Other invested parties, such as the federal government, should support additional research and policy changes to increase interoperability of and access to images and radiology reports across settings of care and to reduce the rates of duplicate imaging for all patients. ■

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**REFERENCES**

1. A Data Book: Health Care Spending and the Medicare Program. Medicare Payment Advisory Commission; 2021. Accessed January 14, 2022. [https://www.medpac.gov/wp-content/uploads/import\\_data/scrape\\_files/docs/default-source/data-book/july2021\\_medpac\\_databook\\_sec.pdf](https://www.medpac.gov/wp-content/uploads/import_data/scrape_files/docs/default-source/data-book/july2021_medpac_databook_sec.pdf)
2. Hendee WR, Becker GJ, Borgstede JP, et al. Addressing overutilization in medical imaging. *Radiology*. 2010;257(1):240-245. doi:10.1148/radiol.10100063
3. Bautista AB, Burgos A, Nickel BJ, Yoon JJ, Tilara AA, Amorosa JK; American College of Radiology Appropriateness. Do clinicians use the American College of Radiology Appropriateness criteria in the management of their patients? *AJR Am J Roentgenol*. 2009;192(6):1581-1585. doi:10.2214/AJR.08.1622
4. Flaherty S, Zepeda ED, Morteke K, Young GJ. Magnitude and financial implications of inappropriate diagnostic imaging for three common clinical conditions. *Int J Qual Health Care*. 2019;31(9):691-697. doi:10.1093/itqhc/mzy248
5. Muskens LJLM, Kool RB, van Dulmen SA, Westert GP. Overuse of diagnostic testing in healthcare: a systematic review. *BMJ Qual Saf*. 2022;31(1):54-63. doi:10.1136/bmjqs-2020-012576
6. Sandberg JC, Ge Y, Nguyen HT, et al. Insight into the sharing of medical images: physician, other health care providers, and staff experience in a variety of medical settings. *Appl Clin Inform*. 2012;3(4):475-487. doi:10.4338/ACI-2012-06-RA-0022
7. Turbow S, Sudharsanan N, Rask KJ, Ali MK. Association between interhospital care fragmentation, readmission diagnosis, and outcomes. *Am J Manag Care*. 2021;27(5):e164-e170. doi:10.37765/ajmc.2021.88639
8. Lu MT, Tellis WM, Fidelman N, Qayyum A, Avrin DE. Reducing the rate of repeat imaging: import of outside images to PACS. *AJR Am J Roentgenol*. 2012;198(3):628-634. doi:10.2214/ajr.11.6890
9. Johnson C, Pitypchuk Y, Patel V. Methods used to enable interoperability among U.S. non-federal acute care hospitals in 2017. Office of the National Coordinator for Health Information Technology data brief 43. December 2018. Accessed May 2, 2022. [https://www.healthit.gov/sites/default/files/page/2018-12/Methods-Used-to-Enable-Interoperability-among-U.S.-NonFederal-Acute-Care-Hospitals-in-2017\\_0.pdf](https://www.healthit.gov/sites/default/files/page/2018-12/Methods-Used-to-Enable-Interoperability-among-U.S.-NonFederal-Acute-Care-Hospitals-in-2017_0.pdf)
10. McCormick D, Bor DH, Woolhandler S, Himmelstein DU. Giving office-based physicians electronic access to patients' prior imaging and lab results did not deter ordering of tests. *Health Aff (Millwood)*. 2012;31(3):488-496. doi:10.1377/hlthaff.2011.0876
11. Vest JR, Kaushal R, Silver MD, Hentel K, Kern LM. Health information exchange and the frequency of repeat medical imaging. *Am J Manag Care*. 2014;20(11 spec No. 17):eSP16-eSP24.
12. Smith-Bindman R, Kwan ML, Marlow EC, et al. Trends in use of medical imaging in US health care systems and in Ontario, Canada, 2000-2016. *JAMA*. 2019;322(9):843-856. doi:10.1001/jama.2019.11456
13. AHA Annual Survey Database. American Hospital Association. Accessed November 2, 2021. <https://www.ahadata.com/aha-annual-survey-database>
14. AHA Healthcare IT Database. American Hospital Association. Accessed November 2, 2021. <https://www.ahadata.com/aha-healthcare-it-database>
15. Hospital Readmissions Reduction Program (HRRP). CMS. Updated September 6, 2023. Accessed August 26, 2020. <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html>
16. Rudolph JL, Zanin NM, Jones RN, et al. Hospitalization in community-dwelling persons with Alzheimer's disease: frequency and causes. *J Am Geriatr Soc*. 2010;58(8):1542-1548. doi:10.1111/j.1532-5415.2010.02924.x
17. Berenson-Eggers Type of Service (BETOS) codes. CMS. Accessed May 2, 2022. <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/MedicareFeeforSvcPartsAB/downloads/BETOSDescCodes.pdf>
18. ICD 10 procedure code cheat sheet 2023. Montana Department of Public Health & Human Services. Accessed December 18, 2023. <https://dphhs.mt.gov/assets/publichealth/EMSTS/Trauma/2023ICD10ProcedureCodeCheatSheet.pdf>

19. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40(5):373-383. doi:10.1016/0021-9681(87)90171-8
20. Rural-urban commuting area codes: documentation. US Department of Agriculture. Updated September 25, 2023. Accessed July 20, 2021. <https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/documentation/>
21. Rudin RS, Motala A, Goldzweig CL, Shekelle PG. Usage and effect of health information exchange: a systematic review. *Ann Intern Med.* 2014;161(11):803-811. doi:10.7326/M14-0877
22. Eden KB, Totten AM, Kassakian SZ, et al. Barriers and facilitators to exchanging health information: a systematic review. *Int J Med Inform.* 2016;88:44-51. doi:10.1016/j.ijmedinf.2016.01.004
23. Vest JR, Unruh MA, Freedman S, Simon K. Health systems' use of enterprise health information exchange vs single electronic health record vendor environments and unplanned readmissions. *J Am Med Inform Assoc.* 2019;26(10):989-998. doi:10.1093/jamia/ocz116
24. Chen M, Guo S, Tan X. Does health information exchange improve patient outcomes? empirical evidence from Florida hospitals. *Health Aff (Millwood).* 2019;38(2):197-204. doi:10.1377/hlthaff.2018.05447
25. Daniel OU. Effects of health information technology and health information exchanges on readmissions and length of stay. *Health Policy Technol.* 2018;7(3):281-286. doi:10.1016/j.hlpt.2018.05.003
26. Usher M, Sahni N, Herrigel D, et al. Diagnostic discordance, health information exchange, and inter-hospital transfer outcomes: a population study. *J Gen Intern Med.* 2018;33(9):1447-1453. doi:10.1007/s11606-018-4491-x
27. Platen M, FleBa S, Rädke A, et al. Prevalence of low-value care and its associations with patient-centered outcomes in dementia. *J Alzheimers Dis.* 2021;83(4):1775-1787. doi:10.3233/JAD-210439
28. Mendelson DS, Erickson BJ, Choy G. Image sharing: evolving solutions in the age of interoperability. *J Am Coll Radiol.* 2014;11(12 pt B):1260-1269. doi:10.1016/j.jacr.2014.09.013
29. Lu MT, Tellis WM, Avrin DE. Providing formal reports for outside imaging and the rate of repeat imaging. *AJR Am J Roentgenol.* 2014;203(1):107-110. doi:10.2214/AJR.13.10617
30. Lu MT, Tellis WM, Fidelman N, Qayyum A, Avrin DE. Reducing the rate of repeat imaging: import of outside images to PACS. *AJR Am J Roentgenol.* 2012;198(3):628-634. doi:10.2214/ajr.11.6890

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**eAppendix A. ICD-10 and DRG Codes Used for Index Admissions**

<b>ICD-10 Codes</b>				
	I5032	Q334	J181	A985
I2101	I5033	B330	J188	B650
I2102	I5040	J09X1	J189	B901
I2109	I5041	J09X2	J920	N10
I2111	I5042	J1000	J929	N110
I2119	I5043	J1001	J941	N118
I2121	I509	J1008	J949	N119
I2129	R570	J101	R091	N12
I213	R579	J1100	E860	N135
I214	J411	J1108	E861	N136
I220	J418	J120	E869	N151
I221	J42	J121	E870	N2884
I222	J430	J122	I951	N2885
I228	J431	J123	I952	N2886
I229	J432	J1281	I953	N3000
I0981	J438	J1289	I9581	N3001
I110	J439	J129	R55	N3010
I130	J440	J13	A1810	N3011
I132	J441	J14	A1811	N3020
I501	J449	J153	A1812	N3021
I5020	J470	J154	A1813	N3030
I5021	J471	J157	A3685	N3031
I5022	J479	J159	A5275	N3080
I5023	J684	J160	A5401	N3081
I5030	J688	J168	A5611	N3090
I5031	J689	J180	A5619	N3091

N340	690
N342	880
N343	881
N390	
F05	
R442	
R443	

**DRGs**

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**eAppendix B. BETOS Codes and Body System Codes**

Anatomic Region Name	Body System Character	BETOS Codes
Central Nervous System	0	I2A
Peripheral Nervous System	1	I2C
Heart and Great Vessels	2	I3C
Upper Arteries	3	I3D
Lower Arteries	4	I4A
Upper Veins	5	
Lower Veins	6	
Lymphatic and Hemic system	7	
Eye	8	I1A
Ear, nose, sinus	9	I3A
Respiratory System	B	
Mouth and Throat	C	
Gastrointestinal System	D	I1D
Hepatobiliary System and Pancreas	F	
Endocrine system	G	
Skin and Breast	H	I1B
Subcutaneous Tissue and Fascia	J	I1C
Muscles	K	
Tendons	L	
Bursae and Ligaments	M	
Head and Facial Bones	N	
Upper Bones	P	
Lower Bones	Q	
Upper Joints	R	
Lower Joints	S	
Urinary system	T	I3B
Female Reproductive System	U	I3D
Male Reproductive System	V	
Anatomic Region, General	W	I1E
Anatomic Region, upper extremities	X	I1F
Anatomic Region, Lower extremities	Y	I2B I2D I3F I4B

**eAppendix C. Health Information Exchange Status by Hospital, AHA IT Supplement, 2017-2018**

		Total (n=3436)	HIE (n=2028)	No HIE (n=1408)	p
Urban/rural Status	Metro	63.0%	68.2%	55.5%	<0.0001
	Micro	16.7%	16.1%	17.8%	
	Rural	20.2%	15.7	26.7%	
Region	Midwest	31.7%	31.7%	31.6%	<0.0001
	North	13.4%	15.7%	10.1%	
	South	37.5%	35.9%	39.8%	
	West	17.5%	16.8%	18.5%	
Hospital Bed Size	≥500 beds	7.8%	10.0%	4.5%	<0.0001
	<500 beds	92.3%	90.0%	95.5%	
Hospital Ownership	1	20.7%	16.0%	27.3%	<0.0001
	2	11.4%	14.6%	6.8%	
	3	53.2%	55.9%	49.4%	
	4	14.8%	13.5%	16.6%	
Hospital Type	General	97.4%	97.3%	97.4%	0.8504
	Specialty	2.6%	2.7%	2.6%	
Teaching Status	Yes	44.8%	50.9%	36.0%	<0.0001
	No	55.2%	49.1%	64.0%	

**eAppendix D.** Association of Fragmented Readmissions and Repeat Imaging on the Same Body System, 2018

	<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	1.08 (1.05, 1.12)	1.04 (1.01, 1.08)	1.08 (1.06, 1.12)	1.05 (1.02, 1.08)
<i>AD</i>	1.02 (0.92, 1.12)	0.98 (0.88, 1.08)	1.01 (0.92, 1.12)	0.98 (0.89, 1.08)

a. All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used. Readmission hospital fixed effects were included in each model.

*Model 1: demographics (age, sex, race), Charlson Comorbidity Index, diagnosis related group (DRG) of the readmission*

*Model 2: hospital (urban/rural, size, ownership, type, teaching; each for readmission hospital)*

*Model 3: Full model*

**eAppendix E.** Association of Information Sharing and Repeat Imaging on the Same Body System, 2018

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	1.12 (1.05, 1.18)	1.06 (1.00, 1.13)	1.12 (1.05, 1.08)	1.06 (1.00, 1.13)
	Different HIE	1.12 (1.06, 1.17)	1.08 (1.03, 1.13)	1.12 (1.06, 1.17)	1.08 (1.03, 1.13)
	No HIE	1.08 (1.02, 1.14)	1.04 (0.99, 1.10)	1.08 (1.02, 1.14)	1.05 (0.99, 1.10)
	Missing HIE info	1.06 (0.99, 1.14)	1.03 (1.03, 1.13)	1.06 (0.99, 1.14)	1.03 (0.96, 1.11)
<i>AD</i>	Same HIE	0.91 (0.74, 1.12)	0.89 (0.72, 1.10)	0.90 (0.73, 1.11)	0.89 (0.72, 1.10)
	Different HIE	1.06 (0.90, 1.25)	1.02 (0.87, 1.20)	1.07 (0.91, 1.25)	1.02 (0.87, 1.21)
	No HIE	1.02 (0.85, 1.22)	0.98 (0.81, 1.18)	1.01 (0.84, 1.21)	0.97 (0.80, 1.17)
	Missing HIE info	0.98 (0.77, 1.25)	0.95 (0.74, 1.21)	0.98 (0.77, 1.24)	0.94 (0.74, 1.21)

*b. All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used.*

*Readmission hospital fixed effects were included in each model.*

*Model 1: demographics (age, sex, race), Charlson Comorbidity Index, diagnosis related group (DRG) of the readmission*

*Model 2: hospital (urban/rural, size, ownership, type, teaching; each for readmission hospital)*

*Model 3: Full model*

**eAppendix F.** Association of Information Sharing and Repeat Imaging on the Same Body System Category, By Number of Admission-Readmission Pairs

**A.** One Admission-Readmission Pair Only

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	1.20 (1.13, 1.27)	1.12 (1.05, 1.19)	1.16 (1.09, 1.24)	1.10 (1.03, 1.16)
	Different HIE	1.16 (1.11, 1.22)	1.09 (1.04, 1.15)	1.14 (1.09, 1.20)	1.08 (1.03, 1.13)
	No HIE	1.13 (1.07, 1.19)	1.09 (1.04, 1.15)	1.12 (1.06, 1.18)	1.05 (1.00, 1.11)
	Missing HIE info	1.04 (1.00, 1.08)	1.00 (0.97, 1.04)	1.08 (1.09, 1.20)	1.03 (0.99, 1.07)
<i>AD</i>	Same HIE	0.98 (0.82, 1.18)	0.97 (0.81, 1.16)	0.96 (0.80, 1.15)	0.94 (0.78, 1.13)
	Different HIE	1.12 (0.98, 1.29)	1.08 (0.94, 1.25)	1.10 (0.96, 1.27)	1.06 (0.92, 1.22)
	No HIE	0.99 (0.84, 1.16)	0.94 (0.80, 1.11)	0.96 (0.81, 1.13)	0.92 (0.78, 1.09)
	Missing HIE info	1.01 (0.91, 1.12)	0.98 (0.88, 1.09)	1.02 (0.91, 1.13)	0.99 (0.89, 1.10)

a. All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used.

*Model 1: demographics (age, sex, race), Charlson Comorbidity Index*

*Model 2: hospital (urban/rural, size, region, ownership, control, teaching; each for readmission hospital)*

*Model 3: Full model*

**B.** Two or More Admission-Readmission Pairs

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	1.18 (0.92, 1.49)	1.10 (0.86, 1.39)	1.20 (0.95, 1.52)	1.13 (0.89, 1.44)
	Different HIE	1.06 (0.87, 1.30)	1.09 (0.89, 1.34)	1.11 (0.91, 1.36)	1.15 (0.94, 1.41)
	No HIE	0.96 (0.79, 1.18)	0.99 (0.80, 1.22)	1.03 (0.84, 1.26)	1.05 (0.85, 1.29)
	Missing HIE info	1.00 (0.86, 1.16)	1.07 (0.91, 1.26)	1.05 (0.90, 1.23)	1.11 (0.94, 1.31)
<i>AD</i>	Same HIE	0.51 (0.17, 1.57)	0.43 (0.14, 1.31)	0.43 (0.14, 1.35)	0.34 (0.11, 1.08)
	Different HIE	0.64 (0.33, 1.25)	0.53 (0.26, 1.08)	0.68 (0.33, 1.39)	0.58 (0.27, 1.21)
	No HIE	0.57 (0.28, 1.17)	0.63 (0.29, 1.35)	0.62 (0.29, 1.31)	0.73 (0.33, 1.61)
	Missing HIE info	0.68 (0.36, 1.29)	0.68 (0.35, 1.32)	0.81 (0.42, 1.56)	0.87 (0.44, 1.72)

a. *All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used.*

*Model 1: demographics (age, sex, race), Charlson Comorbidity Index*

*Model 2: hospital (urban/rural, size, region, ownership, control, teaching; each for readmission hospital)*

*Model 3: Full model*

**eAppendix G.** Association of Information Sharing and Repeat Imaging on the Same Body System Category, MRI During Index Admission

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	0.95 (0.69, 1.31)	0.92 (0.64, 1.32)	0.97 (0.69, 1.34)	0.93 (0.65, 1.34)
	Different HIE	1.18 (0.88, 1.59)	1.28 (0.94, 1.73)	1.18 (0.88, 1.59)	1.28 (0.94, 1.74)
	No HIE	0.96 (0.69, 1.34)	0.98 (0.70, 1.37)	0.97 (0.69, 1.34)	0.98 (0.70, 1.37)
	Missing HIE info	1.32 (0.88, 1.98)	1.38 (0.94, 1.73)	1.32 (0.88, 1.98)	1.39 (0.90, 2.14)
<i>AD</i>	Same HIE	0.85 (0.18, 4.05)	0.75 (0.16, 3.57)	0.85 (0.18, 4.05)	0.75 (0.16, 3.57)
	Different HIE	1.06 (0.14, 7.95)	0.85 (0.11, 0.64)	1.06 (0.14, 7.95)	0.85 (0.11, 6.40)
	No HIE	0.53 (0.07, 3.76)	0.37 (0.04, 3.28)	0.53 (0.07, 3.76)	0.37 (0.04, 3.28)
	Missing HIE info	3.48 (0.60, 20.17)	4.17 (0.04, 3.28)	3.48 (0.60, 20.17)	4.17 (0.60, 29.02)

*c. All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used.*

*Readmission hospital fixed effects were included in each model.*

*Model 1: demographics (age, sex, race), Charlson Comorbidity Index*

*Model 2: hospital (urban/rural, size, region, ownership, control, teaching; each for readmission hospital)*

*Model 3: Full model*

**eAppendix H.** Association of Information Sharing and More than One Repeat Image on the Same Body System

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	1.35 (1.03, 1.77)	1.35 (1.03, 1.77)	1.34 (1.02, 1.76)	1.34 (1.02, 1.75)
	Different HIE	0.92 (0.70, 1.22)	0.92 (0.69, 1.22)	0.92 (0.69, 1.22)	0.92 (0.69, 1.22)
	No HIE	1.00 (0.79, 1.25)	0.99 (0.79, 1.25)	0.99 (0.79, 1.25)	0.99 (0.79, 1.25)
	Missing HIE info	0.95 (0.67, 1.35)	0.94 (0.66, 1.34)	0.95 (0.67, 1.35)	0.94 (0.66, 1.34)
<i>AD</i>	Same HIE	1.91 (0.39, 9.37)	1.91 (0.37, 9.88)	1.91 (0.39, 9.37)	1.91 (0.37, 9.88)
	Different HIE	0.81 (0.30, 2.22)	0.83 (0.30, 2.28)	0.81 (0.30, 2.22)	0.83 (0.30, 2.28)
	No HIE	0.74 (0.26, 2.04)	0.71 (0.26, 1.96)	0.74 (0.26, 2.04)	0.72 (0.26, 1.96)
	Missing HIE info	0.47 (0.09, 2.45)	0.49 (0.09, 2.53)	0.47 (0.09, 2.45)	0.49 (0.09, 2.53)

*a.* All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used.

Readmission hospital fixed effects were included in each model.

*Model 1:* demographics (age, sex, race), Charlson Comorbidity Index

*Model 2:* hospital (urban/rural, size, region, ownership, control, teaching; each for readmission hospital)

*Model 3:* Full model

**eAppendix I.** Association of Information Sharing and Repeat Imaging on the Same Body System Category, Any Advanced Imaging (CT/MRI/US)

		<i>Unadjusted</i>	<i>Demographic</i>	<i>Hospital</i>	<i>Full</i>
<i>No AD</i>	Same HIE	1.67 (1.06, 2.62)	1.62 (1.03, 2.53)	1.60 (1.01, 2.53)	1.58 (1.00, 2.49)
	Different HIE	0.68 (0.35, 1.32)	0.67 (0.35, 1.30)	0.68 (0.35, 1.32)	0.67 (0.35, 1.32)
	No HIE	1.82 (1.25, 2.63)	1.77 (1.23, 2.56)	1.77 (1.20, 2.61)	1.76 (1.20, 2.58)
	Missing HIE info	1.19 (0.83, 1.69)	1.18 (0.83, 1.68)	1.30 (0.90, 1.88)	1.28 (0.89, 1.84)
<i>AD</i>	Same HIE	1.84 (0.64, 5.26)	1.81 (0.63, 5.18)	1.69 (0.59, 4.82)	1.70 (0.60, 4.83)
	Different HIE	2.08 (0.89, 4.86)	2.08 (0.89, 4.87)	2.12 (0.91, 4.94)	2.14 (0.92, 4.98)
	No HIE	0.84 (0.25, 2.79)	0.84 (0.25, 2.80)	0.83 (0.25, 2.75)	0.83 (0.25, 2.77)
	Missing HIE info	0.50 (0.17, 1.44)	0.50 (0.17, 1.44)	0.61 (0.21, 1.74)	0.61 (0.21, 1.73)

a. All analyses are compared to pairs readmitted to the same hospital/nonfragmented readmissions. Robust standard errors clustered at the hospital level were used. Model 1: demographics (age, sex, race), Charlson Comorbidity Index

Model 2: hospital (urban/rural, size, region, ownership, control, teaching; each for readmission hospital)

Model 3: Full model