

# Fragmentation of Care and the Use of Head Computed Tomography in Patients With Ischemic Stroke

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**Background**—Computed tomographic (CT) scans are central diagnostic tests for ischemic stroke. Their inefficient use is a negative quality measure tracked by the Centers for Medicare and Medicaid Services.

**Methods and Results**—We performed a retrospective analysis of Medicare fee-for-service claims data for adults admitted for ischemic stroke from 2008 to 2009, with 1-year follow-up. The outcome measures were risk-adjusted rates of high-intensity CT use ( $\geq 4$  head CT scans) and risk- and price-adjusted Medicare expenditures in the year after admission. The average number of head CT scans in the year after admission, for the 327 521 study patients, was 1.94, whereas 11.9% had  $\geq 4$ . Risk-adjusted rates of high-intensity CT use ranged from 4.6% (Napa, CA) to 20.0% (East Long Island, NY). These rates were 2.6% higher for blacks than for whites (95% confidence interval, 2.1%–3.1%), with considerable regional variation. Higher fragmentation of care (number of different doctors seen) was associated with high-intensity CT use. Patients living in the top quintile regions of fragmentation experienced a 5.9% higher rate of high-intensity CT use, with the lowest quintile as reference; the corresponding odds ratio was 1.77 (95% confidence interval, 1.71–1.83). Similarly, 1-year risk- and price-adjusted expenditures exhibited considerable regional variation, ranging from \$31 175 (Salem, MA) to \$61 895 (McAllen, TX). Regional rates of high-intensity CT scans were positively associated with 1-year expenditures ( $r=0.56$ ;  $P<0.01$ ).

**Conclusions**—Rates of high-intensity CT use for patients with ischemic stroke reflect wide practice patterns across regions and races. Medicare expenditures parallel these disparities. Fragmentation of care is associated with high-intensity CT use. (*Circ Cardiovasc Qual Outcomes*. 2014;7:430-436.)

**Key Words:** Medicare ■ multidetector computed tomography ■ stroke

The prevalence of stroke in the United States was 2.6% in 2008. Care for survivors cost an estimated \$18.8 billion during the same year.<sup>1</sup> Ischemic stroke, comprising the majority of all stroke cases, has been associated with considerable racial and regional variability.<sup>2-4</sup> In addition to the inherent variation in the presentation and natural history of the disease, shortfalls in the quality of care, particularly across race and ethnicity, have been documented.<sup>2,3</sup> In the current setting of evolving accountable healthcare models,<sup>5</sup> the measurement of treatment patterns associated with small patient benefit (or possible harm) and high costs becomes increasingly important. Within this context, the Centers for Medicare and Medicaid Services are especially targeting excessive use of medical imaging,<sup>6</sup> including head computed tomography (CT). Although CT scans are key in diagnostic radiology, their overuse is associated with increased cancer risk for the exposed populations.<sup>7</sup>

Little is known about resource utilization, and in particular the use of medical imaging, in ischemic stroke. In the current analysis, we examined regional variation for 2 key measures of resource utilization in ischemic stroke across Hospital Referral

Regions (HRRs). The first was the incidence of high-intensity CT use, which was defined as  $\geq 4$  head CT scans billed in the year after admission. Head CT is the first line of diagnostic test used, and its overuse can be associated with significant health risks for the exposed populations.<sup>7</sup> The degree of CT use is an individualized decision tailored to the particular patient's condition and the preference of the treating physician. Although this decision is often based on a changing neurological examination, it is common practice to monitor patients with elective head CT scans, despite the lack of clinical change. This latter practice can lead to inappropriate overuse. We investigated the association of fragmentation of care, defined as the number of different physicians seen, with the rate of high-intensity CT use across different regions and races.

The second outcome measure was average Medicare expenditures for the year after the index admission for ischemic stroke. We hypothesized that risk- and price-adjusted expenditures (adjusted for comorbidities and baseline regional differences in prices) will vary across regions and exhibit a positive correlation with increased CT use. We tested our hypotheses using a 2008 to 2009 cohort of patients with ischemic stroke,

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### WHAT IS KNOWN

- In the current setting of evolving accountable healthcare models, the measurement of treatment patterns associated with small patient benefit (or possible harm) and high costs becomes increasingly important.
- Within this context, the Centers for Medicare and Medicaid Services are especially targeting excessive use of medical imaging,<sup>6</sup> including head computed tomography (CT).
- Although CT scans are key in diagnostic radiology, their overuse is associated with increased cancer risk for the exposed populations.
- Little is known about resource utilization, and in particular the use of medical imaging, in ischemic stroke.

### WHAT THE STUDY ADDS

- Significant geographic and racial variation in high-intensity CT use in the year after acute ischemic stroke was observed throughout the United States.
- Increased use paralleled spending in corresponding Hospital Referral Regions, with similarly pronounced regional variation.
- Greater fragmentation of care was found to be associated with high-intensity head CT use. In addition, black patients demonstrated greater fragmentation of care and increased high-intensity CT use.
- The association of fragmentation of care with higher rates of high-intensity CT use supports the need for a stronger postdischarge network that will promote efficiency and quality of care.

in the Medicare fee-for-service population, with follow-up data running through 2010.

## Methods

### Study Population

After approval by the Dartmouth Committee for Protection of Human subjects, we used all data for Medicare beneficiaries enrolled in fee-for-service programs or non-risk-bearing health maintenance organizations from 2008 to 2009 to calculate the cases of ischemic stroke classified as primary code 433 or 434 of the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*. Coding for stroke has shown good agreement with medical record review<sup>8,9</sup> by calculating their sensitivity, specificity, and positive and negative predictive values. Exclusion criteria included the following: transfers from hospitals other than the treating facility; patients with *ICD-9-CM* codes 433.x0 and 434.x0 (based on the coding characteristics, these were felt to represent transient ischemic attacks) or secondary *ICD-9-CM* codes 430 (subarachnoid hemorrhage) and 431 (intracerebral hemorrhage); cases with missing race, zip code, income, or poverty measures; patients not matched to treating hospitals; and subjects aged  $\geq 100$  years.

### Outcome Variables

Two risk-adjusted outcome variables were defined. The first was the total number of head CT scans (based on current procedural

terminology codes) that a patient had during the year after the index hospital event, with a particular focus on the percentage of patients with  $\geq 4$  head CT scans (high-intensity CT use). This cutoff was selected because it was 1 SD above the average number of head CT scans used for the entire cohort. The second was the total fee-for-service Medicare reimbursements during the same period of time. Medicare reimbursements were price adjusted to control for some regions receiving more payments because of greater cost of living, disproportionate-share hospitals subsidy programs, or graduate medical education payments; the methods and approach have been summarized elsewhere.<sup>10</sup> The risk adjustment was based on the comorbidities discussed below.

### Comorbidities and Regions

Sex-age categories (65–69, 70–74, 75–79, 80–84, 85–99 years of age) were created, as well as 5 ethnicity and race categories (Asian, black, Hispanic, Native American, and other, with white being the reference category). The enrollee's zip code was used to match to 2000 Census data on income and poverty. We then created income quintiles but also added the zip-level poverty rate as a separate variable to reflect the differing distribution of income within the zip code.

Comorbidities, analyzed in the models (Table I in the Data Supplement), included myocardial infarction, arrhythmia, congestive heart failure, hyperlipidemia, coagulopathy, hypertension, peripheral vascular disease, tobacco use, diabetes mellitus, and chronic renal failure. The use of these comorbidities as risk adjusters has been demonstrated before for patients with stroke in the Medicare population<sup>11</sup> and in other databases.<sup>12</sup>

Hierarchical condition categories (HCCs) during the 6 months before admission were created based on the Statistical Analysis Software code provided by the Centers for Medicare and Medicaid Services. These risk scores are a proxy for health status, with higher scores indicating more severe illness and higher expected use of healthcare services. Although the purpose of HCCs was to create a risk adjustment approach for expenditures, they are also a highly predictive measure of mortality.<sup>13</sup> One disadvantage of HCCs, however, is that they are highly correlated with diagnostic intensity, leading to an overdiagnosis bias. Specifically, more intensive regions diagnose otherwise similar patients with more diseases.<sup>13,14</sup> The HCCs were divided into quintiles.

We used the HRR to measure the geographic region. The Dartmouth Atlas of Healthcare identifies 306 such regions. An HRR is a region served by a hospital or group of hospitals that offers cardiovascular and neurosurgical procedures so that each HRR includes  $\geq 1$  tertiary care hospital. All zip codes in the United States were assigned to an HRR on the basis of the migration patterns of hospital use among the elderly population. The definitions of HRRs have not been updated despite market changes for several reasons. First, consistent and fixed HRR-level definitions are necessary for longitudinal analysis of growth patterns among HRRs. Second, new definitions of HRRs are required only to the extent that migration patterns, particularly for tertiary hospitals, change, which has not been observed.

We also investigated the association of fragmentation of care with the disparities of high-intensity CT use. Fragmentation of care was measured by the number of different doctors visited by the patient within a year after the admission for ischemic stroke. The number of different providers was determined by the different National Provider Identifying numbers assigned to each patient. Because sicker patients are often seen by a larger number of different physicians, we risk-adjusted individual physician visits using age, sex, race, comorbidities, and HCC measures and then aggregated these risk-adjusted measures to an average by HRR. We then created quintiles of HRR-level fragmentation.

Quintiles of all variables were created so that the populations across quintiles were equal. We used quintiles instead of generalized semiparametric coefficients as a tradeoff between flexibility and ease of interpretation for readers. We checked for misspecification by considering deciles of the variables in question, which provide even greater flexibility. There was no evidence of the violation of monotonicity or strong nonlinearities; indeed, these coefficients suggested a linear association.

## Statistical Analysis

To identify the factors associated with increased high-intensity CT scan use, we performed a logistic regression analysis at the level of the individual with HRR-level fixed effects, with the dependent variable equal to 1 if the patient had  $\geq 4$  head CT scans during the year after admission. The regression included race, quintiles of the HCC score (to allow for nonlinearities in how the HCC score is associated with CT scans), risk-adjusted fragmentation of care at the HRR level, and the comorbidity and age-adjusted variables mentioned above.

A linear probability regression with the same covariates was also used to create risk-adjusted measures of high-intensity CT scan use. The interpretation of the HRR-level coefficient in the linear probability model was the expected fraction of otherwise identical (and average) patients receiving  $\geq 4$  head CT scans in that region. A second linear probability model was used to create stable HRR-level risk-adjusted measures of use that add up to the actual US national average.

A third linear regression analysis was also performed for Medicare expenditures incurred during the year after hospital admission. This expenditure measure included all part A and B Medicare reimbursements but did not include patient copay or part D drug spending. All expenditure measures were adjusted for differences in Medicare reimbursement rates across regions so that New York City expenditures (for example) are comparable to those in Enid, OK.<sup>10</sup>

In sensitivity analysis, we repeated the analysis using only patients alive during the entire 1-year postadmission period to investigate the effect of excluding patients who died early and were therefore less likely to undergo multiple head CT scans. Regression analysis was also repeated without using HCC as risk adjusters and with different dependent variables (total number of head CT scans and MRIs and total number of any CT within 1 year after admission as the outcome variables). Results of these regression analyses were similar and therefore are not reported below (Tables II–V in the Data Supplement). In addition, we examined whether the regional variation is mitigated if we consider all head imaging. The correlation coefficient between average head MRI use and head CT use at the regional level was 0.18 ( $P < 0.01$ ), meaning that they are not used as substitutes. There was a slightly larger coefficient of variation for average head MRI and CT use (0.105) compared with head CT use alone (0.098). Thus, considering MRI combined with CT scans did not reduce regional variation.

Finally, we included measures of concentration within the HRR. We constructed the Herfindahl/Hirschman Index for each of the HRRs using the specific hospitalization data for patients with ischemic stroke and included this in a separate regression. We observed that less concentration is associated with a higher likelihood of high CT use, but the remaining coefficients (most importantly the association of high-intensity CT use with fragmentation of care) are not changed appreciably from the previous analysis and are therefore not reported here. Additional analyses considered were ordinal regression and Poisson regression. However, ordinal regression approaches involve responses that cannot be assigned numbers, for example, a regression that explains self-reported health as excellent, very good, good, and so forth. In this case, we have readily measured cardinal measures, that is, counts of CT scans. On the contrary, a Poisson regression would be difficult to interpret for a clinical journal.

All variables were retained in the final regression models. All  $P$  values are the results of 2-sided tests, and the level of significance was set at  $P < 0.01$  given the large sample size.

## Results

### Regional Variations in 1-Year Head CT Use

A total of 327 521 patients (mean age, 79.8 years; median age, 80 years; 59% women; 10.6% blacks, and 1.6% Hispanics) with ischemic stroke were identified in the Medicare Claims Data from 2008 to 2009 after applying the exclusion criteria (Figure in the Data Supplement; Table 1). Figure 1A demonstrates the regional variation of high-intensity CT use ( $\geq 4$  head CT scans) in the first year after admission. The average number of head CT scans in the year after admission for

**Table 1. Demographics**

Variable	Mean $\pm$ SD	Fragmentation Index (First Quintile)	Fragmentation Index (Fifth Quintile)
Age, y	79.8 $\pm$ 7.9	79.6	80.5*
Percentage of black	10.6 $\pm$ 30.8	7.9	12.6*
Percentage of Hispanic	1.6 $\pm$ 12.5	1.5	2.3*
Percentage of women	59.7 $\pm$ 49.1	59.7	60.2*
Percentage of arrhythmia	31.1 $\pm$ 46.3	30.6	33.4*
Percentage of diabetes mellitus	25.4 $\pm$ 43.5	25.4	25.0
Percentage of coagulopathy	1.8 $\pm$ 13.2	1.6	1.8*
Percentage of myocardial infarction	26.7 $\pm$ 44.2	25.0	28.7
Percentage of chronic renal failure	10.5 $\pm$ 30.7	9.9	10.5*
Percentage of hypertension	71.3 $\pm$ 45.2	70.2	72.4*
Percentage of hyperlipidemia	34.4 $\pm$ 47.5	31.3	35.1*
Percentage of lung disease	2.2 $\pm$ 14.7	2.0	2.1
Percentage of peripheral vascular disease	6.3 $\pm$ 24.3	6.2	6.0
Percentage of congestive heart failure	15.1 $\pm$ 35.8	15.8	14.8*
HCC (average)	2.54 $\pm$ 1.43	2.42	2.72*
Average number of different MDs seen (1 y after admission)	20.0 $\pm$ 13.4	15.6	24.8*
Zip code income, \$	44 698 $\pm$ 17 221	\$39 023	\$51 400*
Average number of CT scans	1.94 $\pm$ 1.56	1.73	2.19*
Medicare expenditures per patient, \$ (1 y after admission)	\$43 463 $\pm$ 39 127	\$40 330	\$47 518*

n=327 521 for total sample, n=65 553 for quintile 1, and n=65 375 for quintile 5. CT indicates computed tomography; and HCC, hierarchical condition categories. MDs indicates medical doctors.

\*Significance at  $P < 0.001$  level in  $t$  test comparison of quintile 5 with quintile 1 (note that we use a  $P$  value of 0.001 given the large sample sizes).

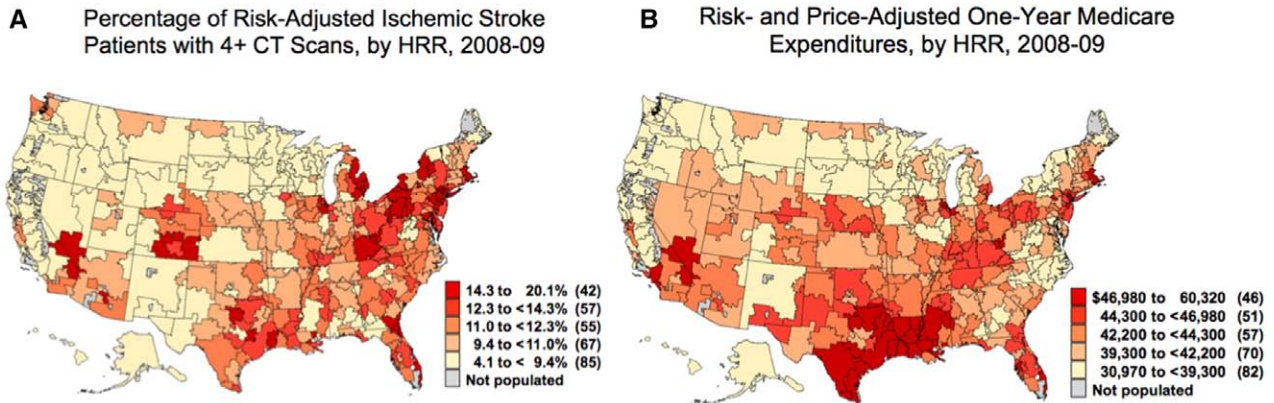
stroke was 1.94 (average [SD], 2.14 [1.7] for blacks and 2.14 [1.8] for Hispanics), whereas 11.9% of the patients had  $\geq 4$ . Regionally, risk-adjusted rates of increased CT use are demonstrated in Table 2 and ranged from 4.6% in Napa, CA, to 20.0% in East Long Island, NY. Large urban centers, such as New York City, Chicago, Boston, Philadelphia, and Miami, demonstrated high rates of high-intensity CT use as shown in Table 2.

In contrast, regions such as Napa, CA, and Albuquerque, NM, exhibited low rates of high-intensity CT use. Furthermore, several regions, such as Grand Junction, CO, were not reported in Table 2 because Center for Medicare and Medicaid Services requires suppressing data reporting with  $< 11$  people in the numerator or denominator.

### Racial Variations in 1-Year Head CT Use

Average risk-adjusted rates of increased CT use were 2.6% higher for black patients than for white patients (95% confidence interval, 2.1%–3.1%), but there was considerable variation across regions, with Flint, MI, experiencing much greater increased CT use rates for black patients with stroke (22.0% for blacks compared with 9.6% for whites) and Augusta, GA,





**Figure 1.** Map of the United States demonstrating (A) the percentage of risk-adjusted patients with ischemic stroke with  $\geq 4$  head computed tomographic (CT) scans by Hospital Referral Region (HRR) and (B) risk- and price-adjusted 1-year expenditures by HRR, 2008 to 2009.

experiencing much lower rates (8.6% for blacks compared with 13.0% for whites).

### Fragmentation of Care

The hypothesis that the number of different doctors seen (conditional on health status) is associated with the rates of high-intensity CT use was tested in a regression analysis. The patients included in this study were seen on average by 20 different physicians in the year after admission. Figure 2A demonstrates a positive association between the level of fragmentation and the rates of high-intensity CT use. Relative to people living in regions with the lowest quintile of fragmentation, the adjusted odds ratio of receiving  $\geq 4$  head CT scans was 1.77 (95% confidence interval, 1.71–1.83) in the highest fragmentation quintile. In additional statistical analysis (Figure 2B), we found that black Medicare beneficiaries were more likely to see a large number of different physicians even after adjusting for health status and sociodemographic factors (4.87 additional different physicians; 95% confidence interval,

4.56–5.20), a phenomenon that is associated with a higher chance of receiving  $\geq 4$  head CT scans. Female sex was found to be associated with a lower rate of fragmentation of care.

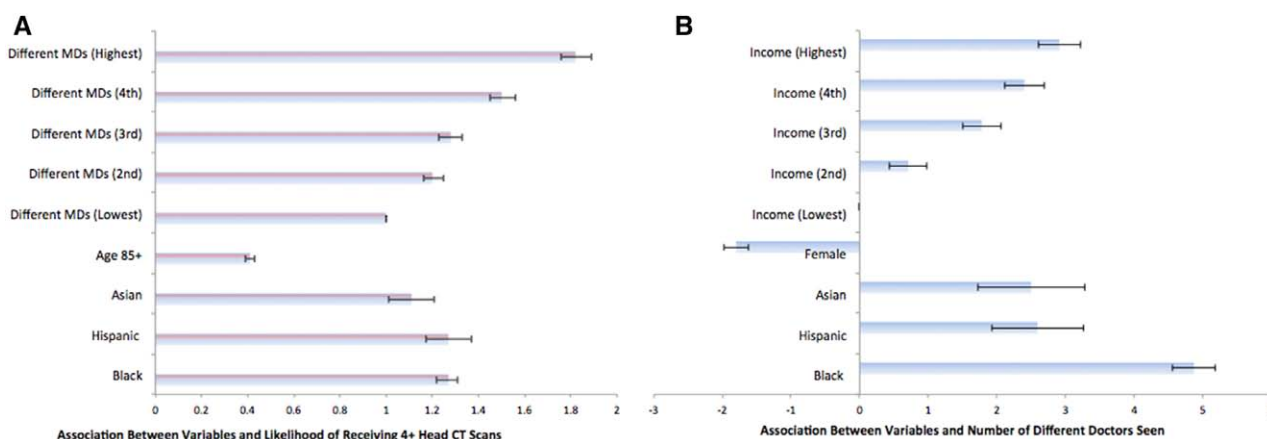
### Variation in 1-Year Risk- and Price-Adjusted Medicare Expenditures

Mean expenditures per patient with ischemic stroke in the United States were \$43 463 (median was \$29 774). Figure 1B demonstrates the regional variation in risk- and price-adjusted 1-year Medicare expenditures for ischemic stroke. These ranged from \$31 175 in Salem, MA, to \$61 895 in McAllen, TX. Regionally, risk- and price-adjusted rates of high-intensity CT use are shown in Table 2 for the HRRs with diverse CT use. Large urban centers, such as New York City, Chicago, Boston, Philadelphia, and Miami, demonstrated high expenditures that often paralleled high rates of CT use. Figure 3 demonstrates moderate positive correlation between regional rates of average high-intensity CT scan use and price- and risk-adjusted Medicare expenditures (Pearson  $r=0.56$ ;  $P<0.01$ ).

**Table 2. Risk-Adjusted Fraction of  $\geq 4$  Head CT Scans in the Year After Admission for Ischemic Stroke, Price- and Risk-Adjusted Expenditures, and Selected Hospital Referral Regions, 2008–2009**

Hospital Referral Region	Rank	No. of Observations	Adjusted Fraction $\geq 4$ CT Scans	CI	Price- and Risk-Adjusted Expenditures	CI
Napa, CA	3	318	0.046	0.023–0.069	\$35 469	\$32 396–38 541
Albuquerque, NM	15	1024	0.065	0.050–0.081	\$38 450	\$36 317–40 583
San Francisco, CA	54	1027	0.082	0.065–0.099	\$42 869	\$40 470–45 268
Minneapolis, MN	56	2346	0.083	0.073–0.094	\$38 478	\$37 201–39 756
Los Angeles, CA	86	5713	0.094	0.086–0.102	\$52 395	\$51 036–53 754
Birmingham, AL	137	3434	0.107	0.097–0.118	\$41 581	\$40 398–42 765
Boston, MA	277	5824	0.147	0.138–0.156	\$48 150	\$47 100–49 201
Manhattan, NY	284	3862	0.155	0.143–0.166	\$48 058	\$46 693–49 422
Philadelphia, PA	297	4329	0.166	0.155–0.177	\$45 553	\$44 355–46 752
Chicago, IL	299	2952	0.169	0.155–0.183	\$52 298	\$50 464–54 132
Miami, FL	301	2180	0.171	0.155–0.188	\$57 251	\$55 277–59 226
Flint, MI	305	879	0.190	0.164–0.217	\$44 913	\$42 250–47 576
East Long Island, NY	306	4699	0.200	0.189–0.212	\$44 622	\$43 544–45 700

In 2 regions, the risk-adjusted rates were below those for Napa, CA, but were not reported because  $<11$  people were receiving  $\geq 4$  head CT scans. Center for Medicare and Medicaid Services precludes the reporting of data with  $<11$  people. CI indicates confidence interval; and CT, computed tomography.



**Figure 2.** Graphic representation of the results of 2 regression models. **A**, The graph demonstrates the respective odds ratios (logistic regression) for the association of several risk factors with high-intensity computed tomography (CT) use ( $\geq 4$  head CT scans in the year after admission for ischemic stroke). **B**, The graph demonstrates the respective  $\beta$  values (linear regression) for the association of several risk factors with increased fragmentation of care. Factors included in the regression models were age, sex, race, income quintiles, comorbidities, and Hierarchical Condition Categories quintiles. The error bars represent the respective 95% confidence intervals. MDs indicates medical doctors.

## Discussion

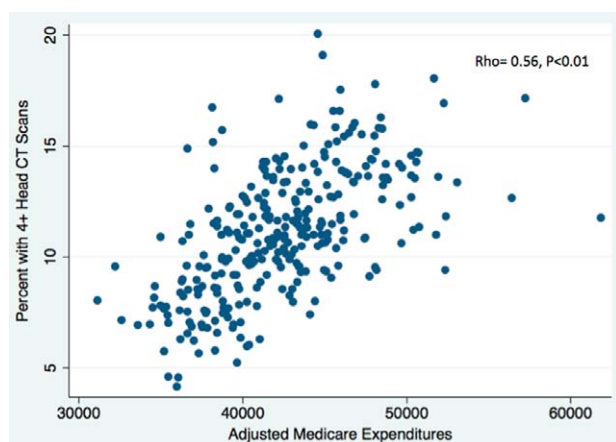
Ischemic stroke is a prevalent disease,<sup>15</sup> but little is known about its use or expenditure patterns across regions. Head CT, as a first-line diagnostic test, with potentially dangerous effects from overuse, is a good target to evaluate efficiency in medical imaging use in stroke, especially among minority groups.<sup>7</sup> This is of particular importance given the increasing monitoring of the overuse of imaging modalities in Medicare patients.<sup>6</sup> Inefficient use of CT exposes patients to increased radiation and is a negative quality indicator tracked by the Hospital Compare Data as part of the Centers for Medicare and Medicaid Services Hospital Quality Initiative.<sup>6</sup> Identifying patterns of increased use, and the reasons behind them, is important for cost-effective healthcare delivery.

Significant geographic variation in high-intensity CT use for acute ischemic stroke was observed throughout the United States. Large urban centers demonstrated the most pronounced rates of increased use. Across HRRs we observed

a positive correlation between high-intensity CT use and risk- and price-adjusted rates of Medicare expenditures in the year after the initial admission. This observation suggests that high-intensity CT use may be a symptom of more inefficient care, rather than the sole causal factor generating higher expenditure costs. Other reasons explaining the remaining variation in CT scans relative to spending include the differential use of postacute care across regions and different practice patterns throughout the country with regard to the use of other diagnostic tests and treatments.

In addition to the prominent regional variations, CT use in patients with stroke demonstrated significant racial disparities, with higher rates of high-intensity CT use among black and Hispanic Medicare beneficiaries. The Institute of Medicine has demonstrated lower rates of evidence-based practices in blacks.<sup>16</sup> This trend has been confirmed for cardiovascular pathology by several groups.<sup>17</sup> Rather than the underuse of effective treatments, this study examines the increased use of a potentially harmful diagnostic test. Administrative data, including HCC scores, may not be able to adjust for the higher severity of stroke among black patients perfectly. However, our finding that in some areas the rates of high-intensity CT use are higher for blacks than for whites, whereas in some others the opposite is true, suggests that inadequate risk adjustment for stroke severity alone cannot explain the patterns we observe.

Although significant attention has been paid to the standardization of inpatient care in patients with stroke,<sup>18,19</sup> little emphasis has been put on the benchmarking of postacute care in this population.<sup>20,21</sup> Greater fragmentation of care was found to be associated with the observed regional and racial disparities in high-intensity CT use during the year after admission for ischemic stroke. Visiting several different providers might account for inconsistent medical records and lack of continuity of care, resulting in larger numbers of redundant diagnostic tests with lower yield. Independent factors associated with more visits with different physicians include minority racial status and higher income groups. The former association could be the result of the lack of continuity of primary care



**Figure 3.** Scatter plot demonstrating the association between high-intensity computed tomography (CT) use ( $\geq 4$  head CT scans in the year after admission for ischemic stroke) and risk- and price-adjusted 1-year expenditures by Hospital Referral Region, 2008 to 2009 (Pearson  $r=0.56$ ;  $P<0.01$ ).

among black or Hispanic patients given the social barriers to which these populations are exposed. However, higher income groups might have a tendency to seek additional opinions and eventual doctor shopping, resulting in higher consumption of healthcare resources.

O'Toole et al<sup>20</sup> have demonstrated that system fragmentation, gaps in human and financial resources, and complexity at the interorganizational and operational levels are common barriers for effective resource utilization. Fragmentation of the current poststroke chain of care could benefit from improved discharge planning, electronic medical records, and evidence-based neuro-rehabilitation guidelines.<sup>20,21</sup> A holistic approach to the patient with frequent postdischarge phone calls and home visits by the same group of physicians could minimize such fragmentation. In addition, overall health policy modifications, such as payment or other market-based reforms, health planning (through state planning departments), or voluntary planning (as in the American Board of Internal Medicine Foundation choosing wisely campaign), can minimize the degree of fragmentation and the inefficient use of imaging technology.

The overuse of head CT scans, in addition to its important implications for health policy design, can have a clear population health impact.<sup>7,22</sup> Although the development of CT represents the single most important advance in diagnostic radiology, and has changed the field of stroke, inefficient use can have detrimental effects.<sup>7</sup> With their current use, it is estimated that 1.5% to 2.0% of all cancers in the United States can be attributed to radiation, largely from CT studies.<sup>7</sup> This provides another reason that policymakers should seek to identify regions where patients are treated in a fragmented setting.

The present study has several limitations common to administrative databases. Indication bias and residual confounding could account for some of the observed associations. In addition, coding inaccuracies can affect our estimates. However, several reports have demonstrated that coding for stroke has shown good correlation with medical record review.<sup>8,9</sup> Third, our data are based on the Medicare population, with potentially different results for the commercially insured. That said, Medicare accounts for a large fraction of ischemic stroke and often leads to policy changes among insurance providers.<sup>23</sup> Fourth, we measure fragmentation by use of the total number of different physicians seen. Although the measure is imperfect, it does reflect the fundamental challenges of coordinating care across multiple physicians. Although some conditions might predispose to excessive fragmentation and hence excessive CT use, we controlled for the patients' baseline health using comorbidities and HCCs, the latter which, if anything, overadjusts for health status.<sup>13</sup>

Fifth, our data were not able to account for degree of impairment, National Institutes of Health stroke score, and rehabilitation needs. To the extent that these needs are associated with the HCC score (a powerful predictor of mortality), our estimates of variation are appropriate. Sixth, stroke mortality was not assessed in our study because of the concerns raised about the use of HCC adjustments in the analysis of mortality differences across regions.<sup>24</sup> Seventh, Medicare does not track the use of nonprescription medications such as aspirin, and therefore we could not control for this important factor. Finally, causality cannot easily be established based on ecological data. Although the

variation described here is strongly suggestive of the inefficient use of resources, it is challenging to predict the effect of different policy initiatives on utilization patterns and continuity of care.

## Conclusions

Ischemic stroke is a prevalent disease, but little is known about its diagnostic or expenditures patterns across regions. Significant geographic and racial variation in high-intensity CT use in the year after acute ischemic stroke was observed throughout the United States. Increased use paralleled spending in corresponding HRRs, with similarly pronounced regional variation. Greater fragmentation of care was found to be associated with high-intensity head CT use. In addition, black patients demonstrated greater fragmentation of care and increased high-intensity CT use. The association of fragmentation of care with higher rates of high-intensity CT use supports the need for a stronger post-discharge network that promotes efficiency and quality of care.

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## Disclosures

None.

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