Radiology

Variations in the Intensive Use of Head CT for Elderly Patients with Hemorrhagic Stroke[1]

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Purpose: To investigate the variability in head computed tomographic (CT) scanning in patients with hemorrhagic stroke in U.S. hospitals, its association with mortality, and the number of different physicians consulted.

Materials and Methods: The study was approved by the Committee for the Protection of Human Subjects at Dartmouth College. A retrospective analysis of the Medicare fee-for-service claims data was performed for elderly patients admitted for hemorrhagic stroke in 2008–2009, with 1-year follow-up through 2010. Risk-adjusted primary outcome measures were mean number of head CT scans performed and high-intensity use of head CT (six or more head CT scans performed in the year after admission). We examined the association of high-intensity use of head CT with the number of different physicians consulted and mortality.

Results: A total of 53272 patients (mean age, 79.6 years; 31377 women [58.9%]) with hemorrhagic stroke were identified in the study period. The mean number of head CT scans conducted in the year after admission for stroke was 3.4; 8737 patients (16.4%) underwent six or more scans. Among the hospitals with the highest case volume (more than 50 patients with hemorrhagic stroke), risk-adjusted rates ranged from 8.0% to 48.1%. The correlation coefficient between number of physicians consulted and rates of high-intensity use of head CT was 0.522 ($P < .01$) for all hospitals and 0.50 ($P < .01$) for the highest-volume hospitals. No improvement in 1-year mortality was found for patients undergoing six or more head CT scans (odds ratio, 0.84; 95% confidence interval: 0.69, 1.02).

Conclusion: High rates of head CT use for patients with hemorrhagic stroke are frequently observed, without an association with decreased mortality. A higher number of physicians consulted was associated with high-intensity use of head CT.

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There is growing concern over the potential health effects and rising costs attributed to excessive use of computed tomographic (CT) scans in the United States (1). In light of these considerations, a substantial number of investigators in the literature are questioning the use of conducting multiple CT scans in various contexts, including the management of blunt trauma (2–5), seizures (6), and chronic headaches (7). It has been estimated (1) that 0.4% of all cancers nationally may be attributable to radiation from CT studies. Excess CT use also contributes to rising costs, with $14 billion spent on imaging in 2006 by Medicare alone (8). These concerns helped catalyze the "Choosing Wisely" campaign (9) and the Centers for Medicare & Medicaid Services Hospital Quality Initiative (10) to measure and report on potentially avoidable CT use. Current efforts by Medicare (10) focus on the inefficient use of abdominal and thoracic CT studies, as well as head CT scans for sinus disease.

Little is known, however, about the magnitude of variations across hospitals in the avoidable use of CT scans or the underlying causes of overuse. Proposed explanations include defensive medicine, clinician uncertainty, consumer demand, financial incentives, and ownership of facilities (1,11–15). Some have also hypothesized that many repeat CT scans are performed because information from prior scans may be unavailable to a clinician at the time of care (1). If this latter explanation were true, advances in technology, such as health information exchanges, or models of payment that encourage integration and coordination, such as Accountable Care Organizations (ACOs), might offer an approach to reducing overuse (16).

This phenomenon can particularly be studied in patients with hemorrhagic stroke who undergo one or several head CT scans at baseline to guide diagnosis and surgical decision making. Potential overuse could expose this population to clinically significant radiation risks. In the current analysis, we studied a 2008–2009 cohort of Medicare fee-for-service patients with hemorrhagic stroke, with follow-up data running through 2010, to examine hospital-level variation in the use of head CT scans during the index hospital admission and the year after the stroke. We investigated the variability in head CT scan use for patients with hemorrhagic stroke in U.S. hospitals (including a subanalysis of the highest-volume hospitals with more than 50 cases of hemorrhagic stroke), its association with mortality, and the number of different physicians consulted.

Advances in Knowledge

- Hospitals throughout the United States are characterized by different intensity of head CT scan use (up to sixfold variation) for similar patients with hemorrhagic stroke.
- These disparities persisted among the centers with the highest volume of hemorrhagic stroke, with risk-adjusted rates of conducting more than six head CT scans in 1 year ranging from 8.0% to 48.1%.
- A higher mean number of different physicians consulted was associated with increased high-intensity use of head CT, both nationwide and among the highest-volume hospitals.
- There was no improvement in 1-year mortality for patients undergoing six or more head CT scans (odds ratio, 0.84; 95% confidence interval: 0.69, 1.02).

Materials and Methods

Cohort

The study was approved by the Committee for the Protection of Human Subjects at Dartmouth College. We used data for Medicare beneficiaries aged 65 years and older who were enrolled in fee-for-service programs or non–risk-bearing health maintenance organizations from 2008 to 2009. This is a sample of 100% fee-for-service Medicare claims provided to the analytic core of The Dartmouth Institute for Health Policy and Clinical Practice by the Centers of Medicare & Medicaid Services. The sample included cases of hemorrhagic stroke classified as primary code 430 (subarachnoid hemorrhage) or 431 (intracerebral hemorrhage) of the *International Classification of Diseases, Ninth Revision, Clinical Modification,* or ICD-9-CM. Exclusion criteria included patients with history of hemorrhagic stroke; transfers from hospitals other than the treating facility; ICD-9-CM codes 873.0–873.9 (traumatic hemorrhage); patients with missing race, zip code, income, or poverty measures; patients not matched to treating hospitals; and subjects older than 100 years. The small group of patients older than 100 years was excluded to prevent any potential compromise in confidentiality, in accordance with the Medicare rule of not reporting data involving fewer than 11 subjects. This cohort was representative of elderly patients with hemorrhagic stroke, since most elderly patients in the United States receive coverage from Medicare.

Implication for Patient Care

- Coordinated efforts are needed to minimize disparities in the use of head CT scans in patients with hemorrhagic stroke.

Outcome Variables

The risk-adjusted primary outcome variables were *(a)* mean number of head

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Abbreviations:
ACO = Accountable Care Organization
CI = confidence interval

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Guarantors of integrity of entire study, K.B., J.S.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, K.B., J.S.; experimental studies, W.Z.; statistical analysis, K.B., W.Z., J.S.; and manuscript editing, K.B., E.S.F., N.L., J.S.

Conflicts of interest are listed at the end of this article.

CT scans conducted per patient over a 1-year period after admission for hemorrhagic stroke, where the date of admission is the first day of the 1-year period, and *(b)* high-intensity use of head CT over the same 1-year period. We defined high-intensity use of head CT as being higher than 1 standard deviation from the mean, which corresponded to six or more head CT scans conducted in the year after admission. The number of head CT scans was determined by identifying the appropriate Current Procedural Terminology codes on part B Medicare claims. These claims occur whether the patient is an inpatient or outpatient or in the postacute setting. The secondary outcome variable was risk-adjusted mortality in the year after admission.

Exposure Variables

Patient sex and age categories (65–69 years, 70–74 years, 75–79 years, 80–84 years, and 85–99 years) were created, as well as five 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 the 2000 U.S. Census data on income and poverty level, which in turn was used to create quintiles of income (with an equal number of patients in every quintile). The actual poverty rate was included to reflect the differing distribution of income within the zip code.

Comorbidities, for which outcomes were adjusted (Table E1 [online]), included myocardial infarction, arrhythmia, congestive heart failure, hyperlipidemia, coagulopathy, hypertension, peripheral vascular disease, lung disease, diabetes, and chronic renal failure. These were used as individual variables, instead of already used comorbidity indexes, since they provide superior disease-specific risk adjustment. We additionally created a dummy variable for subarachnoid hemorrhage to control for hospitals treating a proportionally high number of patients with this condition, since the clinical course of patients with subarachnoid hemorrhage is different than that of the general hemorrhagic stroke population.

Hierarchical condition categories during the 6 months prior to admission were created on the basis of the SAS statistical package (SAS Institute, Cary, NC) code provided by the Centers for Medicare & Medicaid Services. The hierarchical condition categories reflect the diagnosis of diseases prior to admission and are highly predictive of mortality at the individual level. Their use in small-area analysis has been questioned in previous studies because regions with higher intensity of diagnostic testing tend to exhibit higher hierarchical condition category scores, even for patients with similar health status (17,18). This creates a bias toward finding that more intensive health care leads to better health outcomes (17,19). For the purpose of the analysis, hierarchical condition category scores were divided into quintiles, with an equal number of patients in every quintile.

We considered hospitals with patients admitted for hemorrhagic stroke during 2008–2009 as our basic unit of observation. We further investigated whether the disparities persisted among the highest-volume hospitals by selecting institutions with more than 50 hemorrhagic stroke cases. We analyzed this subgroup separately to investigate whether high-volume hospitals demonstrate the same variability patterns, because we expected a more homogeneous patient population to be treated at these hospitals.

We also investigated the association between number of physicians consulted and intensity of head CT use. The number of different physicians consulted within a year after admission for hemorrhagic stroke was determined by examining the National Provider Identifier numbers assigned to each physician on part B claims. To address concerns that this metric might be a proxy for sicker patients, we calculated the correlation index between 1-year mortality and the number of different physicians consulted during the same time. This value was −0.0086, which is essentially zero.

Statistical Analysis

A linear regression model with random hospital effects was used to estimate hospital-level risk-adjusted measures of average head CT scans and high-intensity use of head CT. Best linear unbiased prediction estimates for hospital-specific measures were estimated by using Stata 11 software ("xtmixed" command, with residuals specified with the "reffects" command; StataCorp, College Station, Tex) (20). Best linear unbiased predictions shrink hospital-level estimates toward the mean, depending on sample sizes, and thus resemble empirical Bayes approaches but use sample-based estimates of error variances. A linear random-effects probability model (as opposed to a nonlinear model) was used to avoid computational instability.

We created scatterplots (and calculated Pearson ρ coefficients) to test whether our measure of fragmentation was correlated with risk-adjusted rates of high-intensity use of head CT at the hospital level. These are shown for all U.S. hospitals and separately for the hospitals with more than 50 hemorrhagic stroke cases.

To identify the association of high-intensity use of head CT with mortality, we performed a separate logistic regression analysis at the level of the patient with hospital-specific random effects, with mortality within 1 year of admission being the dependent variable. High-intensity head CT use was a binary variable in this regression. The regression also included as independent variables all comorbidity and age adjustment variables discussed previously. This analysis was restricted to hospitals with at least 25 patients with hemorrhagic stroke.

In the sensitivity analysis, to avoid spurious associations between the exposure variable and the outcome variable—for example, patients who die within 3 days of admission are unlikely to undergo as many head CT scans as those surviving the entire year—we created measures of both mean number of head CT scans and high-intensity use of head CT at the hospital level among those who survived the entire year, again restricted to hospitals with at least 25 patients

Table 1

Patient Characteristics

Variable	Value
Patient age (y)*	79.6 ± 7.7
Race	
Black	4741 (8.9 ± 28.5)
Hispanic	1012 (1.9 ± 13.8)
Women	13 425 (58.9 ± 49.1)
Comorbidities	
Arrhythmia	10 335 (25.2 ± 43.4)
Diabetes	2184 (19.4 ± 39.6)
Coagulopathy	13 347 (4.1 ± 19.8)
Myocardial Infarction	3942 (21.3 ± 41.0)
Chronic Renal Failure	37 131 (7.4 ± 26.2)
Hypertension	12 839 (69.7 ± 45.9)
Hyperlipidemia	639 (24.1 ± 42.8)
Lung Disease	5594 (1.2 ± 10.9)
Peripheral vascular disease	2078 (3.9 ± 19.3)
Congestive heart failure	5594 (10.5 ± 30.6)
Health system measures*	
No. of different physicians consulted (1 year after admission)	19.5 ± 16.4
No. of head CT scans	3.4 ± 3.1

Note.—Data are numbers of patients, with mean percentage ± standard deviation in parentheses, unless indicated otherwise. The total sample included 53 272 patients.

* Data are means ± standard deviations.

with stroke. We also used a measure of high-intensity use of head CT (six or more head CT scans) limited to those scans performed at the admitting hospital for the index admission. The results of these analyses were nearly identical to our primary analyses and are therefore not reported here. All probability values are the results of two-sided tests, and the level of significance was set at $P < .05$. SAS version 9.4 (SAS Institute) and Stata 11 software (StataCorp) were used for the analysis.

Figure 1

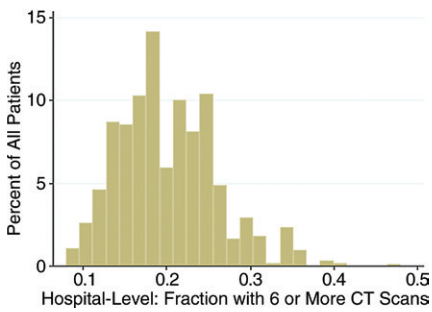

Figure 1: Histogram demonstrates the ratio of risk-adjusted high-intensity use of head CT (six or more head CT scans) among U.S. hospitals.

Results

Hospital Variation in 1-Year Head CT Use

A total of 53 272 patients (mean age, 79.6 years; 31 377 women [58.9%]) with hemorrhagic stroke were identified in the Medicare Claims Data from 2008 to 2009, after applying the exclusion criteria (Fig E1 [online], Table 1). The mean number of head CT scans in the year after admission for hemorrhagic stroke was 3.4 (95% confidence interval [CI]: 3.3, 3.5); the median was two (interquartile range, 1–4), while the mean 1-year mortality rate was 56.9% (95% CI: 56.0, 56.8).

Figure 1 demonstrates the hospital-level variation of risk-adjusted high-intensity use of head CT (six or more head CT scans) in the 1st year after admission. The rate of high-intensity use of head CT ranged from 12.5% for the 10th percentile hospital to 25.3% for the 90th percentile hospital, with the highest rate of 48.1% for Temple University Hospital.

Considerable variation was shown among the hospitals with the highest volume of hemorrhagic stroke. As shown in Table 2, Hartford Hospital, University Hospitals Case Medical Center, Emory University Hospital, and the Mayo Clinic (Rochester, Minn) demonstrated risk-adjusted rates of average head CT scans (2.8, 3.3, 2.9, and 3.2, respectively), as well as risk-adjusted rates of high-intensity use of head CT (9.6%, 10.1%, 12.9%, and 14.5%, respectively) that are below the national average for patients with hemorrhagic stroke. Other hospitals with high hemorrhagic stroke volume, such as Northwestern Memorial Hospital, University of Illinois Medical Center at Chicago, and Temple University Hospital, exhibited significantly higher risk-adjusted mean rates of head CT scans (7.4, 7.5, and 6.9, respectively) and risk-adjusted rates of high-intensity use (39.5%, 41.4%, and 48.1%, respectively). Variability for high-intensity use was observed even within the same city—for example, between Beth Israel Deaconess Medical Center and the Brigham and Women's Hospital (18.7% vs 27.8%).

We found similar patterns of variability in high-intensity use of head CT limited to the cohort who survived the entire year, with a correlation coefficient of 0.89 ($P < .01$) with the entire cohort. We also considered the sensitivity of our results to using only the number of head CT scans performed during the initial index admission. While the fraction of patients who underwent six or more head CT scans was obviously lower (8737 patients [16.4%]), the rankings of the hospitals were similar.

Number of Different Physicians Consulted

Medicare enrollees visited a mean of 19 different physicians in the year after a hemorrhagic stroke, with variation across hospitals ranging from 12.8 to 28.1. The association between the mean number of physicians consulted and high-intensity use of head CT was positive and significant in the sample of 819 U.S. hospitals (Fig 2) with at least 25 patients with hemorrhagic stroke (overall $\rho = 0.52$, $P < .01$). There was also a strong positive association between the level of number of physicians consulted and the risk-adjusted rates of high-intensity head CT use among the highest-volume hospitals ($\rho = 0.50$, $P < .01$).

Table 2

Use of Risk-adjusted Head CT for Hemorrhagic Stroke in Hospitals with the Highest Volume of Hemorrhagic Stroke Cases (more than 50 cases)

Hospital	Patients Who Underswent High-Intensity Use of Head CT (%)	Mean No. of Head CT Scans Performed per Patient per Year
St Vincent Mercy Medical Center, Toledo, Ohio	8.0 (1.7, 14.2)	2.7 (2.2, 3.3)
The Toledo Hospital, Toledo, Ohio	9.0 (1.4, 16.6)	2.9 (2.3, 3.6)
Hartford Hospital, Hartford, Conn	9.6 (3.9, 15.3)	2.8 (2.3, 3.3)
Mercy Hospital Springfield, Springfield, Mo	9.8 (4.4, 15.2)	3.0 (2.5, 3.4)
University Hospitals Case Medical Center, Cleveland, Ohio	10.1 (4.2, 16.0)	3.3 (2.8, 3.8)
Emory University Hospital, Atlanta, Ga	12.9 (7.5, 18.3)	2.9 (3.3, 3.7)
Duke University Hospital, Durham, NC	13.5 (7.0, 20.0)	3.0 (2.5, 3.6)
Dartmouth-Hitchcock Medical Center, Lebanon, NH	13.5 (7.5, 19.5)	3.6 (3.1, 4.1)
University of California, San Francisco, Medical Center, San Francisco, Calif	14.0 (8.1, 19.8)	3.5 (3.0, 4.0)
Mayo Clinic and St Mary's Hospital, Rochester, Minn	14.5 (8.6, 20.4)	3.2 (2.7, 3.7)
Rhode Island Hospital, Providence, RI	15.0 (9.9, 20.0)	3.4 (2.9, 3.8)
St Louis University Hospital, St Louis, Mo	15.2 (9.4, 21.0)	3.7 (3.2, 4.1)
University of Utah Medical Center, Salt Lake City, Utah	15.4 (8.1, 22.7)	3.5 (2.8, 4.1)
Baylor University Medical Center, Dallas, Tex	15.4 (9.9, 20.9)	3.4 (3.0, 3.9)
Vanderbilt University Medical Center, Nashville, Tenn	15.7 (9.3, 22.1)	3.1 (2.5, 3.6)
Mount Sinai Hospital, Chicago, Ill	16.4 (9.7, 23.2)	3.6 (3.0, 4.1)
University of Kentucky Hospital, Lexington, Ky	16.9 (11.0, 22.7)	3.8 (3.3, 4.3)
Stanford Hospital and Clinics, Stanford, Calif	18.0 (10.8, 25.2)	3.5 (2.9, 4.2)
Capital Health System, Trenton, NJ	18.2 (11.9, 24.6)	3.8 (3.3, 4.3)
Carolinas Medical Center, Charlotte, NC	18.4 (14.0, 22.9)	3.7 (3.3, 4.1)
Beth Israel Deaconess Medical Center, Boston, Mass	18.7 (13.7, 23.7)	4.0 (3.5, 4.4)
Florida Hospital, Orlando, Fla	20.9 (15.6, 26.2)	3.8 (3.3, 4.2)
Henry Ford Hospital, Detroit, Mich	21.5 (14.8, 28.2)	4.4 (3.8, 5.0)
University of Pittsburgh Medical Center Presbyterian, Pittsburgh, Pa	21.6 (17.0, 26.1)	4.1 (3.8, 4.5)
University of Tennessee Health Sciences Center, Memphis, Tenn	21.6 (15.2, 28.0)	3.9 (3.4, 4.5)
University of California, Los Angeles, Medical Center, Los Angeles, Calif	22.5 (15.0, 29.9)	4.2 (3.5, 4.8)
Cleveland Clinic Foundation, Cleveland, Ohio	23.2 (17.5, 28.8)	4.4 (3.9, 4.9)
Massachusetts General Hospital, Boston, Mass	23.2 (18.6, 27.7)	4.0 (3.7, 4.4)
Montefiore Medical Center, New York, NY	23.8 (16.8, 30.9)	3.9 (3.3, 4.6)
University of Alabama Hospital, Birmingham, Ala	24.3 (18.0, 30.5)	4.0 (3.5, 4.6)
University of Maryland Medical Center, Baltimore, Md	25.6 (19.9, 31.4)	4.7 (4.3, 5.2)
Brigham and Women's Hospital, Boston, Mass	27.8 (22.1, 33.5)	5.0 (4.5, 5.4)
Stony Brook University Hospital, Stony Brook, NY	28.9 (22.4, 35.4)	4.5 (3.9, 5.0)
University of Medicine and Dentistry of New Jersey Hospital, Newark, NJ	33.1 (25.9, 40.3)	5.1 (4.4, 5.7)
Harborview Medical Center, Seattle, Wash	34.3 (29.5, 39.1)	5.7 (5.3, 6.1)
Allegheny General Hospital, Pittsburgh, Pa	36.0 (30.0, 42.0)	5.2 (4.7, 5.7)
Ohio State University Medical Center, Columbus, Ohio	36.4 (30.2, 42.6)	5.9 (5.3, 6.4)
Northwestern Memorial Hospital, Chicago, Ill	39.5 (32.7, 46.3)	7.4 (6.8, 8.0)
University of Illinois Medical Center at Chicago, Chicago, Ill	41.4 (34.3, 48.5)	7.5 (6.9, 8.1)
Temple University Hospital, Philadelphia, Pa	48.1 (40.3, 55.8)	6.9 (6.2, 7.6)

Note.—Numbers in parentheses are 95% CIs. The Table includes five hospitals with the lowest intensity of head CT use, five with the highest intensity, and 30 representative hospitals in between. The analysis included 253 hospitals. High-intensity use of head CT was defined as six or more head CT scans conducted in the year after admission for hemorrhagic stroke.

One-Year Risk-adjusted Mortality

The association of 1-year mortality with hospital-level high-intensity use of head CT was evaluated in a regression analysis that controlled for socioeconomic factors, comorbidities, age, quintiles of hierarchical condition categories scores, and race (Table E2 [online]). As expected, increasing age (odds ratio of 2.56 [95% CI: 2.36, 2.78] for age over 85 years, relative to 65–69 years) was associated with higher mortality. The opposite was true for higher income levels (odds ratio of 0.89 [95% CI: 0.83, 0.96] for the highest quintile of income in comparison to the lowest). Finally, there was no significant difference in mortality with respect to high-intensity use of head CT (odds ratio, 0.84; 95% CI: 0.69, 1.02). Because of the well-known biases associated with the use of hierarchical condition categories risk adjustment (17), we also estimated the model without hierarchical condition categories measures (Table E3 [online]), again failing to reject the null hypothesis (odds ratio, 1.06; 95% CI: 0.89, 1.27).

Discussion

In this retrospective study of Medicare enrollees, we demonstrated wide hospital-level variation in the rate of high-intensity use of head CT for patients with hemorrhagic stroke. High intensity was associated with higher numbers of different physicians treating each patient but was not associated with improved survival. These results underscore the importance of initiatives to monitor the overuse of expensive and potentially harmful imaging (9,10). This is of particular significance for our cohort of patients with hemorrhagic stroke who undergo multiple CT scans.

Hospitals throughout the United States were characterized by different intensity of head CT scan use for similar patients. A sixfold variation in the use of intensive head CT scanning across hospitals was present, even after adjusting for differences in patient health status across hospitals and after shrinkage methods were used to

Figure 2

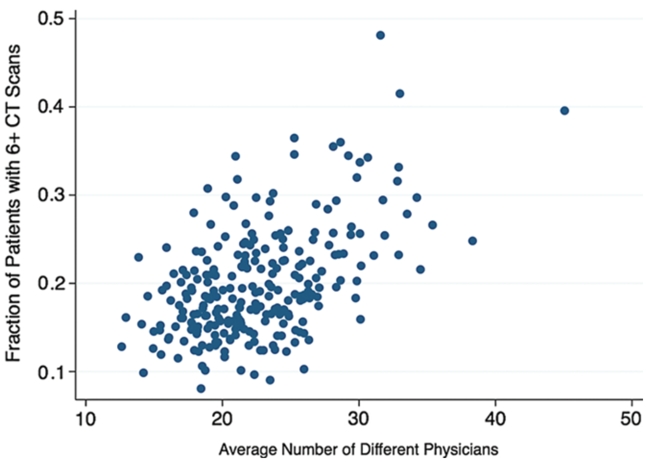

Figure 2: Scatterplot demonstrates the association between risk-adjusted high-intensity use of CT (six or more head CT scans) and risk-adjusted number of different physicians consulted among hospitals with the highest case volume of hemorrhagic stroke (Pearson $\rho = 0.5$, $P < .01$).

reduce the degree of "overfitting" in regression analysis. These disparities persisted among the centers with the highest volume. In particular, patients with hemorrhagic stroke admitted at some hospitals underwent twice the number of head CT studies, on average, in comparison to other highly regarded institutions, such as University of California, San Francisco, and Mayo Clinic, highlighting the lack of universal practices with regard to CT use in this patient population.

The higher mean number of different physicians consulted was associated with increased high-intensity use of head CT, both nationwide and among the highest-volume hospitals. There can be various explanations for this association. Although our results were risk adjusted for several comorbidities, including hierarchical condition categories scores, there is a possibility that the care of sicker patients necessitated more consultations and eventually more head CT scans. Another plausible explanation would be the lack of coordinated care in the hospital systems with more physicians consulted, resulting in more head CT scans (21). This is a challenge that has been identified as a driver of healthcare costs (22). Whether the adoption of value-based payment models for services would improve coordination and minimize unnecessary diagnostic testing, however, is not yet known (22).

Improving the continuity of care and minimizing the number of different physicians overseeing patient care is a recognized goal of several current healthcare reforms, such as ACOs. In the ACO setting, the healthcare providers within the ACO would be held accountable for the entire year of postdischarge services, such as head CT scans, regardless of which institution actually performs the services (23). Hospitals (or ACOs) may be able to reduce the unnecessary use of postacute head CT scans by introducing case managers, discharge planning, electronic medical records, and evidence-based neurorehabilitation guidelines (24,25). O'Toole et al (24) have demonstrated that system fragmentation, gaps in human and financial resources, and complexity at the interorganizational and operational levels are common barriers for effective use of resources. A holistic approach to the patient with frequent postdischarge phone calls and home visits by the same group of physicians could minimize such fragmentation.

Increased high-intensity use of head CT was not associated with lower mortality in the year after admission for hemorrhagic stroke, a result that is consistent with other studies that showed weak or insignificant associations between discretionary medical treatment intensity and health outcomes (26–28). To address concerns that hierarchical condition categories tend to overadjust for risk in hospitals in which CT is used with higher intensity (17), we repeated the analysis without including the hierarchical condition categories as covariates. There was still no association of high-intensity head CT with mortality.

From a clinical perspective, it is important to recognize that this analysis does not address the question of how the amount of care for an individual patient in a specific case would affect the patient's clinical outcome. Nor does our study indicate whether it is possible to reduce overuse and spending. However, if the United States as a whole could safely achieve intensity levels comparable to those of the regions of lowest use, significant cost savings could potentially be realized. Further research is needed to investigate whether such an effect is possible.

The present study has several limitations. First, indication bias (a potential confusion between cause and effect when exposure is dependent on indication) and residual confounding (variables introducing bias that the current study could not control for) could account for some of the observed associations. In addition, coding inaccuracies can affect our estimates, although several reports have demonstrated that coding for hemorrhagic stroke has shown good association with medical record review (29,30). Second, our data are based on the Medicare population, with potentially different results for the commercially insured. Third, we were not able to test the hypothesis that local factors, such as the malpractice environment, affected the propensity to perform additional head CT scans. We found variation in use within cities or states, despite common state malpractice statutes.

Fourth, although using the number of different physicians consulted as a proxy for continuity of care is imperfect, it has been adapted from other prior studies (21,31,32) and appears to reflect the fundamental challenges of coordinating care across multiple physicians. Fifth, we cannot control perfectly for the severity of the hemorrhagic stroke, since measures such as the Glasgow Coma Scale and the National Institutes of Health stroke scale scores are not available. However, we have risk adjusted for socioeconomic factors that are associated with disease severity and for hierarchical condition categories that account for patient health status and are highly predictive of mortality. Despite this, we were still not able to examine the correlation of high-intensity use of head CT with improved neurologic function in 1 year and other functional outcomes. Sixth, we could not account for the proximity of the patient to a CT scanner while hospitalized or the overall use of that scanner. Finally, causality cannot easily be established on the basis of 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 usage patterns and continuity of care.

In conclusion, patients with hemorrhagic stroke frequently undergo several head CT scans as part of their diagnostic work-up and follow-up. Inefficient usage can have detrimental effects on population health and cost (33). We demonstrated significant variability in the use of high-intensity head CT among all U.S. hospitals and among the highest-volume hospitals in hemorrhagic stroke cases. A higher mean number of different physicians consulted was positively associated with high-intensity use of head CT. Increased usage, however, did not correlate with improved mortality in our patient population. The fact that there is so much variation in high-intensity use of head CT suggests a need for coordinated efforts to minimize disparities.

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