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Wide Variation and Rising Utilization of Stroke MRI: Data from Eleven States

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Abstract

Objective—Neuroimaging is an essential component of the acute stroke evaluation. MRI is more accurate than CT for the diagnosis of stroke, but is more costly and time consuming. We sought to describe changes in MRI utilization from 1999–2008.

Methods—We performed a serial cross-sectional study with time trends of neuroimaging in patients with a primary ICD-9-CM discharge diagnosis of stroke admitted through the Emergency Department in the State Inpatient Databases (SID) from 10 states. MRI utilization was measured by Healthcare Cost and Utilization Project (HCUP) criteria. Data were included for states from 1999–2008 where MRI utilization could be identified.

Results—624,842 patients were hospitalized for stroke in the period of interest. MRI utilization increased in all states. Overall, MRI absolute utilization increased 38 percentage points, and relative utilization increased 235% (28% of strokes in 1999 to 66% in 2008). Over the same interval, CT utilization changed little (92% in 1999 to 95% in 2008). MRI use varied widely by state. In 2008, MRI utilization ranged from a low of 55% of strokes in Oregon to a high of 79% in Arizona. Diagnostic imaging was the fastest growing component of total hospital costs (213% increase from 1999–2007).

Interpretation—MRI utilization during stroke hospitalization increased substantially with wide geographic variation. Rather than replacing CT, MRI is supplementing it. Consequently, neuroimaging has been the fastest growing component of hospitalization cost in stroke. Recent neuroimaging practices in stroke are not standardized and may represent an opportunity to improve the efficiency of stroke care.

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Introduction

Neuroimaging is an essential component of acute stroke evaluation. Although MRI has several clear advantages compared to CT in stroke diagnosis, its role in acute stroke management has yet to be completely elucidated. Compared to CT, MRI is a more accurate test for acute ischemia[1–5] and comparably accurate for the detection of intracerebral hemorrhage (ICH).[6] Additional advantages of MRI include the improved ability to detect subtle hemorrhagic changes,[7, 8] to identify stroke location,[9] and in some cases to clarify stroke mechanism.[10–12]

Despite these advantages, downsides to MRI do exist. These include longer scan times and higher costs per scan compared to CT. In addition, there are few data demonstrating that MRI findings lead to changes in patient management versus CT alone.[13] Further, no data yet demonstrate improved outcomes in stroke patients undergoing MRI compared with stroke patients who do not undergo MRI.

In this study, we sought to describe trends in MRI use over the 10-year period of 1999 to 2008 as a means of determining its changing role in routine stroke care and to assess for opportunities to optimize its use. We hypothesized that MRI utilization would increase concordant with overall trends in diagnostic imaging utilization.[14] We further hypothesized that geographic variation in MRI utilization would exist because evidence-based guidelines did not preferentially recommend CT or MRI for stroke evaluation.[15–17] Finally, given prominent societal concerns about health care costs, we sought to characterize costs of MRI and diagnostic imaging during stroke hospitalization. Understanding these trends is essential to the development and implementation of standardized and efficient neuroimaging strategies in stroke.

Methods

Dataset and Study Population

We examined all patients with a discharge diagnosis of stroke in a select group of states from 1999 through 2008. States were chosen to incorporate geographic, temporal and racial variability within the constraints of data availability, consistent participation in SID, data cost, and the ability to identify MRIs. Our specific study population consisted of discharge data from: Washington (1999–2008), New York (1999–2008), Arizona (1999–2008), Florida (1999–2005), Nebraska (2004–2008), Massachusetts (2004–2008), North Carolina (2004–2008), Iowa (2008), Wisconsin (2008), New Jersey (2008) and Oregon (2008).

This study analyzed hospital discharges from State Inpatient Databases (SID) developed as part of the Healthcare Cost and Utilization Project (HCUP), funded by the Agency for Healthcare Research and Quality (AHRQ).[18] The SID consists of abstracts for all acute care discharges within a state for a given year. Discharge abstracts consist of basic demographics, payer information, hospitalization characteristics, charges, primary diagnoses and procedural utilization.

We included all discharges for subjects over 18 years of age in whom the primary discharge diagnosis was ischemic stroke, ICD-9-CM (433.x1, 434.x1, 436)[19] admitted through the emergency department. This approach has been previously validated and found to have a positive predictive value of 88% and sensitivity of 74%.[20]

The University of Michigan Institutional Review Board (IRBMED) determined this study to be exempt from formal review as it relied on publicly available data.

Categorizing Comorbidities

To understand how patient-level variables may influence which patients undergo MRI, we characterized secondary diagnoses in our population of stroke patients. Vascular risk factor and potential stroke mimic diagnoses were characterized using HCUP single-level Clinical Classification System[21] definitions: hypertension (CCS 98,99), diabetes (49,50), hyperlipidemia (53), epilepsy (83), migraine(84). A stroke modified Charlson co-morbidity index was created for each patient using previously described methods.[22, 23]

Measuring Neuroimaging exposure

We measured MRI and CT utilization using the criteria for the Healthcare Cost and Utilization Project’s (HCUP) Magnetic Resonance Technology Utilization and CT Scan flags respectively.[24] These flags define whether a patient underwent any CT or MRI imaging study during their hospitalization and are primarily defined by Uniform Billing (UB-92) revenue codes. UB-92 revenue codes are standardized codes which are automatically generated by hospital billing systems and reflect charges from specific revenue centers.[25] HCUP has internally validated revenue codes for the identification of specific utilization groups, including MRI and CT.[26] This approach was used instead of a less reliable ICD-9-CM procedure code-alone identification strategy because ICD-9-CM strategies are unreliable for procedures that do not change Diagnosis Related Group (DRG) assignment[25] and stroke DRGs are not impacted by whether patients undergo neuroimaging.

Statistical Analysis

To summarize the characteristics of the population demographic information, stroke risk factors, and neuroimaging utilization were reported with percentages or means and standard deviations. Comparisons between those receiving MRI and not receiving MRI were made using t-tests and chi-square tests for continuous and categorical variables respectively. To describe trends in neuroimaging utilization we divided the number of patients receiving a neuroimaging study by the total number of stroke cases identified, stratifying by state and year. Significance of trends was assessed using one-sample t-tests of change in imaging utilization per year to evaluate the null hypothesis that no change in utilization occurred. To account for imbalance in potentially relevant variables, adjusted estimates of MRI utilization by state and over time were generated using multivariate logistic regression accounting for clustering at the hospital level. In both analyses, we adjusted for age, gender, vascular risk factors (hypertension, diabetes, hyperlipidemia, atrial fibrillation), Charlson comorbidity index and insurance status (Medicare vs. Medicaid vs. Private Insurance vs. Other Insurance). Results were reported as mean posterior probabilities with covariates set at population means.

To estimate the availability of MRI and impact of MRI availability on utilization, hospital-level MRI utilization patterns were analyzed. To minimize the impact of miscoded data, a hospital was defined as having established MRI access if 3 or more stroke patients received MRIs at that facility in a given year. This definition will likely underestimate actual MRI access as some hospitals may have the capacity to obtain MRIs and not opt to use that capacity. We then calculated the annual proportion of stroke patients presenting to hospitals with established MRI access.

Next, we sought to quantify geographic variation at the state and Hospital Referral Region (HRR) levels by calculating aggregate MRI utilization rates at both levels by year. HRRs represent discrete geographic regions defined by regional referral patterns for tertiary medical care defined by the presence of at least one hospital that performs major cardiovascular and neurosurgical procedures.[27–29] To measure annual utilization, we aggregated patient-level records at the Hospital Referral Region (HRR) level, calculated

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utilization over HRR, ranked the HRRs by utilization rate and then calculated utilization by HRR quintile.

Finally, we estimated inflation-adjusted costs for the total hospitalization, UB-92 cost categories, MRI and CT. Total hospital charges were abstracted directly from the SID discharge record. All charges within a given UB-92 cost center, identified by revenue code, were summed to derive charges per cost center. MRI and CT costs were calculated by summing costs associated with UB-92 revenue codes 610–619 and 0350–0359 respectively. This approach combines all CT and MRI-related costs into single categories and consequently is not able to distinguish between the costs of repeat imaging studies and of combined imaging studies such as multi-modal imaging. To account for local variation in charges, HCUP cost-to-charge ratios were applied to hospital charges to estimate hospital costs.[30] As a consequence, we were able to estimate actual costs of care as opposed to the amount charged for care. Because we were interested in overall expenditure trends, costs were inflation adjusted to 2008 dollars using the GDP price index.[31] For clarity of reporting, state data was aggregated into two separate time cohorts based on the availability of longitudinal data. Cohort 1 consists of data from New York, Florida, Arizona and Washington from 1999–2007 and cohort 2 consists of data from New York, Arizona, Washington, North Carolina, and Massachusetts from 2004–2008. We report costs for the five largest cost centers. All costs were summarized as means and standard deviations. All data analyses were performed with Stata version 11.1 (Stata Corp, College Station, Texas).

Results

Study Population

Over the 10-year study period (1999–2008), 624,842 primary ischemic stroke hospitalizations were identified. (Table 1) Mean age was 73 ± 14 years and 54% were female. Cardiovascular risk factors were common. Most patients (70%) were insured by Medicare.

MRI was performed in 50% of the total population and CT in 95%. On average, patients who underwent MRI were younger (70 years vs. 76 years, $p < 0.001$), more likely to have private insurance (22% vs. 15%, $p < 0.001$) and had a greater burden of vascular risk factors compared with patients who did not undergo MRI. A history of atrial fibrillation was less common in patients who had an MRI (27% vs. 16%, $p < 0.001$)

Temporal Trends in Diagnostic imaging

From 1999 to 2008, absolute MRI utilization increased 38 percentage points, a relative increase of 235% (28% in 1999 to 66% in 2008, $p = 0.003$ for trend, Figure 1). Of patients receiving an MRI, 95% also received a CT. Overall CT utilization did not change during the same interval (92% in 1999 to 95% in 2008, $p = 0.34$ for trend). After adjusting for the changing age, sex, vascular risk factors, comorbidities and insurance status of the population, each year was associated with a 4.0% increase the probability of receiving MRI in the logistic regression model, (OR 1.20, 95% CI 1.18–1.22).

Regional Variation in Diagnostic Imaging

Utilization of MRI by state is illustrated in Figure 2 for 2008, the year for which the broadest cross-section of data was available. In 2008, MRI utilization ranged from a low of 55% in Oregon to a high of 79% in Arizona. Adjustment for age, sex, vascular risk factors, comorbidities and insurance status had minimal impact on the pattern of variation by state. More extreme geographic variation is seen when analyzing MRI utilization by HRR quintile

(Table 2). In every year, MRI utilization rates were at least 30 percentage points higher in the highest utilizing quintile compared to the lowest utilizing quintile.

Established Access to MRI

There was a modest overall increase in the number of hospitals with established MRI access – 74% of hospitals had access in 1999 vs. 87% in 2008 (p< 0.01) (Table 3). The hospitals that gained MRI access over time were mostly lower volume centers, consequently there was less change in the percentage of stroke patients presenting to hospitals with MRI access — 89% in 1999 vs. 96% in 2008 (p < 0.01). This suggests that physician practice regarding MRI is more important than the availability of MRI scanners *per se* to explain the rising rates of MRI utilization.

Cost Trends

Mean hospital costs increased from $9,058 (SD $11,867) to $12,842 (SD $15,551) in the group of states with most complete cost data (NY, FL, AZ and WA from 1997–2007). Diagnostic imaging, (X-RT, CT, MRI, nuclear medicine, ultrasound, EKG and EEG) was the second largest cost center over this interval behind only Room and Board charges, and underwent the largest percent increase (213%) (Figure 3). MRI costs increased faster than overall Diagnostic Imaging costs, increasing 413% from 1999 to 2007, from 3% of total hospital costs in 1999 to 9% in 2007. CT costs increased by 171% from 6% of total costs in 1999 to 8% in 2007. Similar trends were seen in the group of states with adequate cost data only in the later priod (NY, AZ, WA, NC, and MA from 2004–2008): diagnostic imaging was the second largest cost component and underwent the largest percent increase (129%) with MRI (138%) and CT costs (133%) increasing slightly faster. In 2008, MRI costs accounted for 10% of total hospital costs and CT for 8%.

Discussion

MRI utilization in ischemic stroke has increased substantially from 1999 to 2008. Growth in MRI utilization was seen in every year in every state in our study population. In high utilizing regions, the rate has plateaued at a level suggesting that nearly all eligible patients are receiving MRI.[32, 33] Yet, 95% of patients receiving MRI also received CT; MRI is not replacing CT as the primary stroke neuroimaging study, instead receipt of multiple neuroimaging studies is increasingly common. In addition to an increase in overall MRI utilization, we also observed marked geographic variation. In 2008, 55% of stroke patients underwent MRI in Oregon compared to 79% in Arizona. Partly as a consequence of this widespread increased use, diagnostic imaging has been the fastest growing cost component of stroke care. These data suggest that neuroimaging practices in stroke are neither standardized nor efficient.

The wide geographic variation in MRI utilization demonstrates a potential opportunity to improve stroke care by increasing standardization. This variation was not accounted for by measurable patient characteristics or hospital acquisition of MRI technology. While we cannot directly measure patient preferences, there is little evidence that patients have strong and variable preferences among imaging modalities, independent of the advice of their physicians;[34] it is further unclear why those preferences would be so geographically variable so as to explain the observed pattern. Absent a credible alternative explanation, variation in physician practice patterns likely accounts for much of the variation in MRI utilization

The existence of variation in physician practice in this context is not surprising as variation tends be greater when the evidence for a practice is less certain[29] and stroke imaging guidelines during the study period did not preferentially recommend CT or MRI.[15, 17]

Recent guidelines have generally made more favorable recommendations regarding MRI than previous guidelines, but inconsistency between these guidelines exists. Recently, an American Heart Association (AHA) Scientific Statement was the first major guideline to recommend routine use of MRI or CT angiography for stroke patients.[35] The recent American Academy of Neurology (AAN) guideline on the role of MRI in stroke[36] limits its preferential recommendation of MRI to the period within 12 hours of stroke onset. The most recent European Stroke Organization (ESO) guideline[37] calls for stroke patients to receive either CT or MRI. Standardization of neuroimaging practices may improve as guidelines become more consistent, particularly if evidence emerges that MRI leads to improved outcomes or more optimal physician decision-making. The current highly variable use of MRI suggests that there may be community equipoise that would make a randomized trial ethical, feasible and useful.

Not only are stroke neuroimaging practices non-standardized, but our findings suggest stroke neuroimaging may be unnecessarily costly. In our sample, 95% of patients receiving a MRI also received a CT, thus minimizing the use of multiple imaging studies may represent a viable strategy to contain neuroimaging costs. If the practice of obtaining both MRI and CT reflects physician preference for MRI in a context where CT can be obtained more quickly, then several broad strategies for increasing efficiency are possible. First, some patients may be able to safely wait for an imaging study, allowing MRI to be performed without a preceding CT. Patients with delayed presentations, out of the acute treatment window, and stable examinations might meet these criteria and represent a significant proportion of all stroke patients. Up to 36% of stroke patients present more than 12 hours after onset.[38] Second, wider dissemination of rapid stroke MRI protocols relying on a selective set of sequences (ie: diffusion-weighted, gradient-echo and T2-weighted sequences) may minimize resource utilization and allow for quicker scanner turnover thus enabling earlier MRI acquisition.[39] For MRI to be a viable alternative to CT in the acute stroke period, scan times for MRI must not be greater than CT to minimize time delay for thrombolysis.

This study has several important limitations. First, the use of administrative data to identify stroke is an imprecise process raising the possibility that some of the variability in MRI utilization and cost may be due to imprecision in coding of stroke diagnoses. To minimize this, we have used a previously validated algorithm to identify stroke cases.[19] Similarly, revenue code-based identification of imaging studies is also limited by the inability to reliably identify the subcomponents of an imaging study, the number of times an individual patient received a given neuroimaging study which body part was imaged, or the timing of imaging studies. Consequently, we are unable to reliably determine the role of MRA compared to MRI, which portion of studies were focused on the CNS or when imaging studies were obtained during the hospitalization. Because of this limited information, we can not speculate as to why physicians obtained an MRI in an individual case (ie: was MRI obtained to aid thrombolysis decision making, clarify diagnosis or inform secondary prevention strategies?) Additionally, while our dataset was selected to maximize geographic and demographic variability, the southern states and African Americans are underrepresented.

The use of MRI in ischemic stroke has substantially increased over the last decade, with wide geographic variation and increasing contribution to the cost of stroke care. These findings emphasize the importance of future research to define which stroke patients are likely to benefit from MRI, how MRI information should be applied to individuals, and the relationship between MRI and clinical meaningful outcomes. Finally, these findings illustrate the potential to reduce variability and improve the efficiency of neuroimaging in stroke.

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Dr. Burke had full access to all of the data in the study, performed the primary analyses and takes responsibility for the integrity of the data and the accuracy of the data analysis

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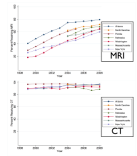

Figure 1.
Utilization Trends in Diagnostic Imaging for Stroke

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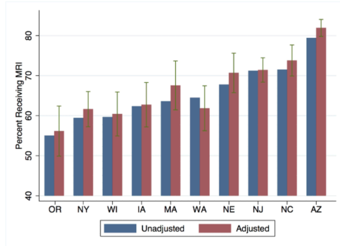

Figure 2. Percent of Stroke Patients Receiving MRI, 2008

Legend: Dark gray bars represent unadjusted utilization by state. Light gray bars represent utilization adjusted for age, sex, vascular risk factors, comorbidities and insurance status.

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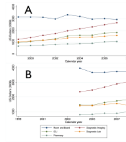

Figure 3. Trends in Stroke Cost Components

Legend: Top Panel: Trends in cost components from 1999–2007 in NY, FL, AZ, WA. Bottom Panel: Trends in cost components from 2004–2008 in NY, AZ, WA, NC, MA

Table 1

Study Population Baseline Characteristics

	MRI (n=310,768)	no MRI (n=314,074)	All Subjects (n=624,842)
Demographics			
Age mean(sd)	70 (14)	76 (13)	73 (14)
Female	52%	57%	54%
Race/Ethnicity			
White	60%	61%	61%
Black	7%	7%	7%
Hispanic	14%	12%	13%
Insurance			
Medicare	64%	75%	70%
Medicaid	8%	6%	7%
Private Insurance	22%	14%	18%
Other Insurance	6%	4%	5%
Comorbidities			
Hypertension	72%	67%	69%
Hyperlipidemia	32%	19%	25%
Diabetes	30%	28%	29%
Coronary Artery Disease	21%	27%	24%
Atrial Fibrillation	16%	27%	21%
Modified Charlson, mean (sd)	3.8 (2)	4.5 (1.9)	4.1 (1.9)

Table 2

MRI Utilization Quintiles by year, defined by Hospital Referral Region (HRR)

	Percent Receiving MRI by HRR utilization Quintile				
Year	**1 (lowest utilizers)**	**2**	**3**	**4**	**5 (highest utilizers)**
1999	7%	17%	23%	29%	39%
2000	10%	21%	27%	35%	50%
2001	17%	28%	35%	42%	55%
2002	22%	31%	41%	51%	63%
2003	23%	36%	45%	57%	66%
2004	31%	45%	51%	64%	72%
2005	34%	47%	55%	66%	74%
2006	34%	52%	55%	62%	77%
2007	36%	55%	60%	66%	77%
2008	43%	58%	64%	70%	78%

Table 3

Hospital availability of MRI

Year	% of Hospitals with MRI access	% of Stroke Patients at Hospital with MRI access
1999	74%	89%
2000	77%	91%
2001	80%	93%
2002	83%	94%
2003	82%	94%
2004	83%	94%
2005	86%	95%
2006	83%	94%
2007	84%	94%
2008	87%	96%