Patients With Acute Ischemic Stroke Who Receive Brain Magnetic Resonance Imaging Demonstrate Favorable In-Hospital Outcomes

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BACKGROUND: Use of inpatient brain magnetic resonance imaging (MRI) in patients with acute ischemic stroke is highly institution dependent and has been associated with increased length and cost of hospital stay. We examined whether inpatient brain MRI in patients with acute ischemic stroke is associated with improved clinical outcomes to justify its resource requirements.

METHODS AND RESULTS: The National Inpatient Sample database was queried retrospectively to find 94,003 patients who were admitted for acute ischemic stroke and then received inpatient brain MRI between 2012 and 2014. Multivariable regression analysis was performed with respect to a control group to assess for differences in the rates of inpatient mortality and complications, as well as the length and cost of hospital stay based on brain MRI use. Inpatient brain MRI was independently associated with lower rates of inpatient mortality (1.67% versus 3.09%; adjusted odds ratio [OR], 0.60; 95% CI, 0.53–0.68; P<0.001), gastrostomy (2.28% versus 2.89%; adjusted OR, 0.82; 95% CI, 0.73–0.93; P<0.001), and mechanical ventilation (1.97% versus 2.82%; adjusted OR, 0.68; 95% CI, 0.60–0.77; P<0.001). Brain MRI was independently associated with ≈0.32 days (8%) and $1131 (11%) increase in the total length (P<0.001) and cost (P<0.001) of hospital stay, respectively.

CONCLUSIONS: Inpatient brain MRI in patients with acute ischemic stroke is associated with substantial decrease in the rates of inpatient mortality and complications, at the expense of marginally increased length and cost of hospitalization.

Key Words: ischemic stroke ■ magnetic resonance imaging ■ outcomes research
suspected acute stroke may have alternative diagnoses on brain MRI.10

There is a paucity of literature, let alone a clear guideline, about use of inpatient brain MRI following the early management of AIS. Although use of inpatient brain MRI in patients with stroke is increasing, there is a high degree of geographical and institutional variability, which has stronger influence than patients’ clinical factors on brain MRI use.11,12 Inpatient brain MRI is most commonly performed in addition to initial CT-based workup, and it has been associated with increased length and cost of hospital stay.12,13

Therefore, an outcome study is warranted to examine whether inpatient brain MRI in patients with AIS will lead to clinical benefit that can justify its resource requirements. Given the institutional heterogeneity in use of inpatient brain MRI for AIS and the multifactorial nature of potential changes in patient management following brain MRI, the effect of inpatient brain MRI on patient outcomes needs to be examined across a large number of institutions. For the present study, we used the clinical data from the National Inpatient Sample (NIS) to test the hypothesis that use of brain MRI in patients admitted with AIS is associated with improved clinical outcomes.

Nonstandard Abbreviations and Acronyms

AIS  acute ischemic stroke
NIS  National Inpatient Sample

CLINICAL PERSPECTIVE

What Is New?

• A significant association exists between inpatient brain magnetic resonance imaging and decreased rates of inpatient mortality and complications in patients with acute ischemic stroke.
• Inpatient brain magnetic resonance imaging was also associated with marginally increased length and cost of hospitalization.

What Are the Clinical Implications?

• Physicians should consider obtaining brain magnetic resonance imaging for all patients admitted with acute ischemic stroke.
• Further studies are needed to establish causality and to characterize the change in stroke management following inpatient brain magnetic resonance imaging to explain the improved outcomes.

METHODS

Patient Database

Anonymized data and materials have been made publicly available at the NIS and can be accessed at http://www.hcup-us.ahrq.gov/nisoverview.jsp. The present study was performed retrospectively using the NIS, a public inpatient database in the United States. Maintained by the Agency for Healthcare Research and Quality, the NIS depicts an ≈20% stratified sample of inpatient admissions at nonfederal hospitals, representing the US population regardless of payer type.14 The database contains information on diagnoses and procedures based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. Three years of data (2012–2014) were used, comprising >21 million discharges from >4000 hospitals in 45 states. The study was conducted in accordance with the US Health Insurance Portability and Accountability Act and did not require local Institutional Review Board approval because of the use of a public database.

Study Population

We queried the NIS database to search for patients aged ≥18 years with the principal diagnosis of AIS. The study population was then stratified into 2 groups based on use of inpatient brain MRI. The baseline characteristics of the control and MRI groups were organized with respect to sex, age, income, and insurance type, as well as hospital characteristics, including location, size, and teaching status. Major comorbidities were also included for characterization, as outlined in Table 1.

Study Outcomes

The primary outcome of the study was in-hospital mortality. The secondary outcomes were resource use (length and cost of hospital stay) and in-hospital complications: intracranial hemorrhage, gastrostomy, mechanical ventilation, and nonhome discharge.

The ICD-9-CM codes used to identify the study population, comorbidities, and outcomes have been outlined in Table 1.

Statistical Analysis

As stated by the developers, the NIS is a self-weighted, stratified, systematic, random sample of discharges from all hospitals in the sampling frame after sorting discharges by diagnosis-related group, hospital, and admission month.15 The NIS sample is stratified on the basis of hospital characteristics, and within each stratum, hospitals (clusters) were selected from the sampling frame at the rate of 100% and discharges from hospitals were sampled at a rate of ≥20% (starting year 2012). Therefore, in our
model, we used statements “egen STA=group (YEAR NIS_STRATUM)” and “svyset [pweight=DISCWT], strata (STA) psu (HOSP_NIS).” The stratum statement specifies NIS_STRATUM as the stratum identifier, and the cluster statement specifies HOSP_NIS as the cluster identifier. We used a survey-specific method, with the commands svyset and svy with pweight using the discharge-level weight from 2012 to 2014 to generate nationwide estimates.16

We used descriptive statistics to compare demographic characteristics and outcomes between patients with AIS with and without MRI of the brain. The baseline characteristics were compared between the MRI and control groups using the χ² test for categorical variables and the Student t test for continuous variables. In our multivariable regression model, we assessed differences in binary outcomes by using logistic regression and in continuous outcomes by using ordinary least squares linear regression.

Analyses were performed using Stata version 14 (StataCorp, College Station, TX). All statistical tests were performed with weighted samples using the survey data analysis tools on Stata.16 All statistical tests were 2 sided, and P<0.05 was considered statistically significant.

**RESULTS**

**Baseline Characteristics**

A total of 94,003 patients who received inpatient brain MRI were identified for the study, the baseline characteristics of whom have been summarized in Table 2 along with the control group. Patients who underwent brain MRI were more likely to be younger (mean age, 69.0±14.2 versus 71.0±14.0 years), be Black, have higher income, and hold private insurance. Patients in the MRI group were more likely to be admitted to large urban teaching hospitals in the northeast region. The patients in the MRI group showed overall decreased prevalence of significant comorbidities, as shown in Table 2. No significant difference in sex was found between the 2 groups.

**Clinical Outcomes**

Unadjusted mortality rate was lower in the MRI group at 1.67% compared with 3.09% in the control group. On multivariable regression analysis, undergoing inpatient brain MRI was independently associated with lower mortality (adjusted odds ratio [OR], 0.60; 95% CI, 0.53–0.68; P<0.001) (Table 3).
Major in-hospital complications were also significantly less likely to occur in the brain MRI group (Table 3). On multivariable regression analysis, brain MRI was independently associated with a significantly lower incidence of gastrostomy (adjusted OR, 0.82; 95% CI, 0.73–0.93; \( p < 0.001 \)) and mechanical ventilation (adjusted OR, 0.68; 95% CI, 0.60–0.77; \( p < 0.001 \)). No significant difference in intracranial hemorrhage (adjusted OR, 1.04; 95% CI, 0.93–1.15; \( p = 0.490 \)) and nonhome discharge (adjusted OR, 1.04; 95% CI, 0.99–1.10; \( p = 0.140 \)) was observed between the 2 groups.

### Resource Use

Unadjusted length of stay was longer in the MRI group at 4.57±5.82 days compared with 4.18±5.33 days (mean±SD) in the control group. On multivariable regression analysis, brain MRI independently accounted for increase in length of hospital stay of \( \approx 0.32 \) days (95% CI, 0.19–0.45 days; \( p < 0.001 \)) (Table 3).

Similarly, the MRI group had higher unadjusted cost of hospital stay at US$11,681±$12,815 compared with US$10,465±$12,113 (mean±SD) in the control group. The estimated effect size of brain MRI on inpatient cost was \( \approx $1131 \) (95% CI, $744–$1527; \( p < 0.001 \)) (Table 3).

### DISCUSSION

In the present study, we used a national database to examine the clinical benefit of inpatient brain MRI for patients admitted with AIS. Compared with the control group, the MRI group showed more favorable baseline characteristics with respect to age, socioeconomic status, care setting, and comorbidities. Therefore, multivariable regression analysis was the central component of the study to isolate the effects of brain MRI.

On multivariable regression analysis, we found that brain MRI was independently associated with
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improved clinical outcomes. Specifically, in-hospital mortality was significantly lower in the brain MRI group, which was accompanied by corresponding reductions in incidence of in-hospital complications. Previously, equivalent or superior clinical outcomes were demonstrated with MRI-guided management compared with CT-guided management of AIS in the emergency setting.5,17–20 Our results extend the clinical benefit of MRI-based management to the subacute period during inpatient admission.

Because MRI only provides diagnostic information, the associated change in patient management responsible for the improved outcomes remains in question. In a previous study, the single best predictor of receiving inpatient MRI for AIS was admission to a dedicated stroke unit,21 consistent with integration of MRI into routine clinical workflow in some stroke units.22 As dedicated stroke unit care has been shown to reduce in-hospital mortality,23–25 the association between brain MRI and stroke unit admission offers a potential explanation for our results. However, in contrast to inpatient stroke unit care, inpatient brain MRI was not associated with improved 1-year outcomes following discharge in a single-institution study where MRI did not change the management decisions known to influence outcome.21,26 Therefore, the treatment changes associated with brain MRI are likely multifactorial with institutional variation, and further studies are needed to explain the improved in-hospital outcomes that we observed.

The present study showed that the benefits of inpatient brain MRI for AIS come at the expense of increased length and cost of hospitalization, as previously found in resource use studies.12,13 When we compared the clinical benefit of brain MRI against its resource requirements, we found that the relative increase in length (8%) and cost (11%) of hospitalization is marginal compared with the degree of mortality benefit (adjusted OR, 0.62), which translates to relative risk reduction of ≈38% with rare outcome assumption.27 Overall, the improved clinical outcomes associated with brain MRI are sufficient to justify its resource use.

The limitations of the present study are as follows. Because we only examined the association between inpatient brain MRI and clinical outcomes retrospectively, the results could not be directly attributed to the effect of brain MRI. Although the downstream changes in patient management following MRI could have caused improved outcomes, obtaining MRI could have simply been a consequence of favorable baseline patient characteristics, such as a lower National Institutes of Health Stroke Scale score or environmental characteristics, such as availability of MRI. Lack of information on the clinical context of receiving MRI is an intrinsic limitation of the NIS database, and it prohibits making any conclusions on causation from our study. Similarly, the lack of information on detailed patient management in the NIS database precluded characterization of the change in management associated with brain MRI. Although imaging studies are underreported in the NIS database,28 statistical power was maintained by enrollment of a large number of subjects through national-level analysis. Furthermore, as a limitation of the database, our study was not able to take into account the different types or timing of MRI, which were previously found to affect the diagnostic performance of MRI and cost of hospital stay.29,30

In summary, inpatient brain MRI in patients admitted with AIS is associated with reduced in-hospital mortality and complications, but with increased length and cost of hospitalization. The clinical benefits associated with inpatient brain MRI outweigh the resource requirements. The present study provides the first evidence for the relationship between inpatient brain MRI and in-hospital outcomes in AIS. A prospective, randomized study is needed to establish causality and

### Table 3. Differences in In-Hospital Outcomes Based on Brain MRI Use

| Outcome                  | Unadjusted Incidence | Adjusted Odds Ratio (95% CI) | P Value |
|--------------------------|----------------------|-----------------------------|---------|
| Mortality, %             | 1.67 vs 3.09         | 0.60 (0.53–0.68)            | <0.001  |
| Intracranial hemorrhage, % | 2.85 vs 2.46         | 1.04 (0.93–1.15)            | 0.490   |
| Gastrostomy, %           | 2.28 vs 2.89         | 0.82 (0.73–0.93)            | <0.001  |
| Mechanical ventilation, % | 1.97 vs 2.82         | 0.68 (0.6–0.77)             | <0.001  |
| Nonhome discharge, %     | 52.41 vs 53.41       | 1.04 (0.99–1.10)            | 0.140   |

| Outcome                  | Unadjusted Value (Mean±SD) | Regression Coefficient (95% CI) | P Value |
|--------------------------|-----------------------------|---------------------------------|---------|
| Length of stay, d        | 4.57±5.82 vs 4.18±5.33      | 0.32 (0.19–0.45)                | <0.001  |
| Cost of hospital stay, US$| 11 681±12 815 vs 10 465±12 113 | 1131 (744–1527)                | <0.001  |

All values are based on MRI group vs control group. MRI indicates magnetic resonance imaging.
to characterize the change in patient management following inpatient brain MRI.

ARTICLE INFORMATION
Received April 27, 2020; accepted August 17, 2020.

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Acknowledgments
The authors acknowledge Jiehui Xu, MPH, at Division of Biostatistics, New York University Grossman School of Medicine, New York, NY, for helpful discussions on statistical methods.

Sources of Funding
The authors recognize support from the Division of Neuroradiology at the University of Pennsylvania Health System to cover the article publication charge.

Disclosures
None.

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