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The Addition of MRI to CT Based Stroke and TIA Evaluation Does Not Impact One year Outcomes

Hebah Hefzy*, Elizabeth Neil, Patricia Penstone, Meredith Mahan, Panayiotis Mitsias and Brian Silver

Henry Ford Hospital, 2799 W. Grand Blvd. Detroit MI 48202, USA

Abstract: *Background*: The 2010 American Academy of Neurology guideline for the diagnosis of acute ischemic stroke recommends MRI with diffusion weighted imaging (DWI) over noncontrast head CT. No studies have evaluated the influence of imaging choice on patient outcome. We sought to evaluate the variables that influenced one-year outcomes of stroke and TIA patients, including the type of imaging utilized.

Methods: Patients were identified from a prospectively collected stroke and TIA database at a single primary stroke center during a one-year period. Data were abstracted from patient electronic medical records. The primary outcome measure was death, myocardial infarction, or recurrent stroke within the following year. Secondary outcome measures included predictors of getting an MRI study.

Results: 727 consecutive patients with a discharge diagnosis of stroke or TIA were identified (616 and 111 respectively); 536 had CT and MRI, 161 had CT alone, 29 had MRI alone, and one had no neuroimaging. On multiple logistic regression analysis, there were no differences in primary or secondary outcome measures among different imaging strategies. Predictors of the primary outcome measure included age and NIHSS, while performance of a CT angiogram (CTA) predicted a decreased odds of death, stroke, or MI. The strongest predictor of having an MRI was admission to a stroke unit.

Conclusions: These results suggest that long-term (one-year) patient outcomes may not be influenced by imaging strategy. Performance of a CTA was protective in this cohort. A randomized trial of different imaging modalities should be considered.

Keywords: Imaging modality, Outcomes, Stroke, MRI, CT.

INTRODUCTION

The 2010 evidence-based guideline on The Role of Diffusion and Perfusion MRI for the Diagnosis of Acute Ischemic Stroke from the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology states that “diffusion-weighted imaging” (DWI) is established as useful and should be considered more useful than noncontrast CT for the diagnosis of acute ischemic stroke within 12 hours of symptom onset”[1]. The 2007 American Stroke Association Stroke Guidelines for the Early Management of Adults With Ischemic Stroke recommendations state that “in most instances, CT will provide the information to make decisions about emergency management” and that “multimodal CT and MRI may provide additional information that will improve diagnosis of ischemic stroke”[2]. The 2009 American Stroke Association Guidelines for the Definition and Evaluation of Transient Ischemic Attack state that “patients with TIA should preferably undergo neuroimaging evaluation within 24 hours of symptom onset. MRI, including DWI, is the preferred brain diagnostic imaging modality. If MRI is not available, head CT should be performed” [3].

Cost based studies looking at direct hospital cost of acute stroke care indicate that patients with more severe strokes incur the greatest hospital costs [4]. This is likely related to the additional cost of tests and procedures. Access to MRI scanners is often limited and MRI images typically become available at a time point in patient care where management decisions have already been made.

The preference for MRI over CT recommended or implied in these guidelines is based primarily on literature showing that MRI is more accurate for the diagnosis of acute cerebral injury in patients with new and sudden neurological change, whether the event lasts more or less than 24 hours [5,6]. In addition, MRI may be more sensitive than CT for the detection of acute hemorrhage [7]. However, CT is faster to obtain and more accessible than MRI, and contraindications to MRI were present in 45% of patients requiring urgent MRI in one study [8]. Preference for MRI over CT in octogenarians for the treatment of acute stroke does not show an improvement in outcome at three months [9]. To date, there have been no studies comparing diagnostic evaluation with or without MRI with respect to long-term patient outcome.

*Address correspondence to this author at the Henry Ford Hospital, 2799 W. Grand Blvd. Detroit MI 48202, USA; Tel: 313-916-3014;
Fax: 313-916-9107; E-mail: hhefzy1@hfhs.org

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We sought to evaluate the outcomes of stroke and TIA patients evaluated and treated at a single tertiary care Primary Stroke Center [10]. The focus of the study was any potential association between imaging strategy and outcome at one year.

METHODS

This single center study was approved by the local institutional review board (IRB # 5867). Patients were identified from a prospectively collected database of stroke and TIA patients at a Primary Stroke Center. All patients admitted to Henry Ford Hospital between January 1, 2008 and Dec 31, 2008 with a discharge diagnosis of ischemic stroke or TIA were included. Data were abstracted from the prospectively collected database and from the patient electronic medical records. Variables that were recorded and whether that information was collected prospectively from the database or retrospectively from the chart review are noted in Table **1**. Patient outcomes up to one year following admission were recorded. The primary outcome measure was death, myocardial infarction, or recurrent stroke within one year. Secondary outcome measures were stroke within one year, myocardial infarction within one year, death within one year, and predictors of an MRI occurring during a hospitalization.

Univariate analyses using Chi-square and Fisher's exact tests were performed for each outcome measure, and multivariable analysis was performed to adjust for any variable which trended towards significance ($p < 0.1$) on univariate analysis including age, median NIHSS score on admission, atrial fibrillation, and vascular risk factors (diabetes mellitus [DM], hypertension, coronary artery disease [CAD], and hyperlipidemia).

RESULTS

Between January 1, 2008 and December 31, 2008, 727 patients were discharged with a diagnosis of stroke or TIA. One patient with TIA did not h ave any neuroimaging and was excluded from further analysis. Of the remaining patients, 161 had CT alone, 29 had MRI alone, and 536 had CT and MRI. Of these patients, 616 had a diagnosis of stroke and 110 had a diagnosis of TIA. Baseline characteristics of patients with CT only and CT with MRI based evaluations are shown in Table **2**. Among other differences, CT only patients were significantly older and had higher median NIHSS scores at admission.

There were 122 deaths, 49 recurrent strokes, and 22 myocardial infarctions within one year of follow-up. Predictors of the primary outcome were age, admission NIHSS, and history of CAD, while performance of a CTA had the opposite effect (OR 0.473, 95% CI 0.262-0.854, p=0.0131). (Table **3**). No other diagnostic study, including any MRI modality, had a significant effect on the primary outcome measure.

For secondary outcome measures, on multivariate analysis, predictors of death included age (OR 1.048, 95% CI 1.028 1.067, p<0.0001), admission NIHSS (OR 1.132, 95% CI 1.096-1.168, p<0.0001), and presence of atrial fibrillation (OR for absence vs. presence = 0.516, 95% CI 0.280 – 0.950, p = 0.0337), while performance of a CTA was protective (OR 0.365, 95% CI 0.173-0.773, p=0.0085) (Table **4**).

Table 1. Variables Collected

Clinical Data:
Length of stay
Age
Sex
Race
Atrial fibrillation (pre-existing or current)
History of congestive heart failure
History of stroke or TIA
History of coronary artery disease
History of diabetes mellitus
History of hypertension
History of peripheral vascular disease
Tobacco use within the previous year
History of carotid stenosis
History of dyslipidemia
History of prosthetic valve
Treatment with tPA
Median NIHSS at admission, discharge, first follow-up visit, and at 1 year
Median mRS at discharge
Labwork:
Cholesterol
Triglycerides
HDL
LDL
Diagnostic Studies:
CT head
MRI brain
CT Angiogram head/neck
MR Angiogram head/neck
Digital subtraction angiography
Carotid Ultrasonography
Transcranial Doppler
Transthoracic or transesophageal echocardiography

TIA = Transient Ischemic Attack, TPA = tissue plasminogen activator, NIHSS = National Institutes of Health Stroke Scale, mRS = Modified Rankin Score, HDL = high density lipoprotein, LDL = low density lipoprotein, CT = Computed Tomography, MRI = Magnetic Resonance Imaging

The primary predictor of stroke and MI was a history of CAD (OR of absence vs. presence = 0.473, 95% CI 0.245-0.913, p= 0.0256 and 0.316, 95% CI 0.132 – 0.754, p = 0.0095 respectively).

The odds of having MRI added to a CT based workup was evaluated after adjusting for previously reported variables and the greatest predictor of having an MRI was admission to a stroke unit (OR 6.0, 95% CI 3.486- 10.325, p <0.0001) (Table **5**).

Table 2. Baseline Characteristics of Patients with CT only Versus CT with MRI Evaluations

Variable	CT only (n=161)	CT with MRI (n = 536)	p-value
Age	71.1 +/- 15.8	65.7 +/- 13.8	<0.001
Female	50%	51%	0.956
Race (Black)	58%	66%	0.083
(White)	39%	30%	
Diabetes Mellitus	35%	35%	0.985
Atrial Fibrillation (pre-existing or current)	26%	8%	<0.001
History of hypertension	79%	80%	0.749
Tobacco use within the previous year	14%	27%	0.001
History of stroke or TIA	26%	24%	0.672
History of coronary artery disease	29%	17%	0.001
History of congestive heart failure	29%	9%	<0.001
History of carotid stenosis	2%	2%	0.722
History of dyslipidemia	30%	37%	0.141
Length of stay (days)	6.5 +/- 6.0	4.4 +/- 3.9	<0.001
History of peripheral vascular disease	3%	0%	0.011
History of prosthetic valve	4%	0%	<0.001
Treatment with tPA	9%	7%	0.307
Median NIHSS score at admission	7	3	<0.001
Median NIHSS score at discharge	4	2	<0.001
Median NIHSS score at first follow-up visit	9	3	<0.001
Median NIHSS score at 1 year	0	0	0.975
Median mRS score at discharge	4	2	<0.001
Total cholesterol at admission (g/dl)	155	171	<0.001
Triglycerides at admission (g/dl)	105	121	0.002
HDL at admission (g/dl)	41	40	0.764
LDL at admission (g/dl)	94	107	<0.001
CTA head and neck	27%	17%	0.009
MRA head and neck	0%	90%	<0.001
Digital subtraction angiography	8%	5%	0.202
Carotid ultrasonography	49%	21%	<0.001
Transcranial doppler	28%	4%	<0.001
Transthoracic/transesophageal echocardiography	82%	93%	<0.001

NIHSS = National Institutes of Health Stroke Scale, mRS = modified Rankin scale

DISCUSSION

The introduction of CT technology for the imaging of the human brain in the early 1970s led to a dramatic change in the diagnosis of stroke [11]. Landmark clinical trials such as the NINDS rt-PA stroke trial [12] and ECASS III [13] would not have been safe to perform with CT imaging because of the approximately 13% of patients who have hemorrhagic stroke as the etiology of their symptoms [14]. MRI technology for human brain imaging was introduced in the early 1980s [15] and diffusion-weighted imaging (DWI)/perfusion

Table 3. Multiple Logistic Regression Results for the Primary Outcome Measure (Stroke, Myocardial Infarction, or Death) Within One Year

Variable	Odds Ratio	95% Confidence Interval	P-Value
Age	1.031	1.016, 1.046	<0.0001
NIHSS on admission	1.104	1.073, 1.136	<0.0001
History of CAD	1.577	1.005, 2.474	0.0474
History of DM	1.464	0.987, 2.171	0.0580
History of atrial fibrillation	1.540	0.884, 2.684	0.1272
CT only	1.914	0.510, 7.187	0.3360
CT and MRI/MRA	1.519	0.494, 4.670	0.4659
CTA	0.473	0.262, 0.854	0.0131
MRA	0.767	0.361, 1.629	0.4899
TCD	0.720	0.369, 1.406	0.3363

NIHSS= National Institutes of Health Stroke Scale, CAD = coronary artery disease, DM = diabetes mellitus, MRA = magnetic resonance angiography, CTA = CT angiography, TCD = transcranial Doppler.
Adjustments were made for age, median NIHSS score at admission, atrial fibrillation, diabetes mellitus, hypertension, coronary artery disease, and hyperlipidemia. Results in italics are statistically significant.

Table 4. Multiple Logistic Regression Results for Death Within One Year

Variable	Odds Ratio	95% Confidence Interval	P-Value
Age	1.048	1.028, 1.067	<0.0001
NIHSS on admission	1.134	1.098, 1.171	<0.0001
History of CAD	1.104	0.629, 1.936	0.7311
Atrial fibrillation	1.954	1.058, 3.611	0.0324
CT only	2.413	0.436, 13.366	0.3133
CT and MRI/MRA	1.613	0.341, 7.623	0.5466
CTA	0.365	0.173, 0.773	0.0085
MRA	0.468	0.192, 1.141	0.0950
Echocardiography	1.322	0.624, 2.799	0.4663
TCD	0.778	0.362, 1.672	0.5206

NIHSS= National Institutes of Health Stroke Scale, CAD = coronary artery disease, MRA = magnetic resonance angiography, CTA = CT angiography, TCD = transcranial Doppler.
Adjustments were made for age, median NIHSS score at admission, atrial fibrillation, diabetes mellitus, hypertension, coronary artery disease, and hyperlipidemia. Results in italics are statistically significant.

imaging for evaluation of acute stroke were introduced in the 1990s [16].

MRI-based evaluations can improve short-term (i.e. 90-day) prognostication of stroke outcome when added to clinical information [17]. The RRE-90 scoring system, based on an analysis of 1,458 consecutive ischemic stroke patients, demonstrated an area under the ROC curve (AUC) of 0.70-0.80. CT-based evaluations also improve short-term (i.e. 90-day) prognostication after TIA [18]. The ABCD(2)I scoring system, based on an analysis of 4,574 patients , demonstrated an AUC of 0.72-0.85. Even clinically based scoring systems such as the Essen Stroke Risk Score (AUC of 0.59 for 1-year risk of recurrent stroke) [19] and the Stroke Prognosis Instrument II (AUC of 0.63 for 2-year risk of recurrent stroke or death) [20] have reasonable prognostic values. At this time, there are no studies to show the additional value of neuroimaging, in addition to clinical variables, for prognosis beyond 90 days. Furthermore, increasing refinement of prognostication of stroke risk with atrial fibrillation, reflected in the new CHA_2DS_2-VASc score, do not include any neuroimging variables yet show impressive 10-year risk predictions (C statistic of 0.888) [21].

In this single center study of stroke and TIA patients, the addition of MRI to a CT based work-up was not associated

Table 5. Predictors of Having MRI in Addition to CT

Variable	Odds Ratio	95% Confidence Interval	P-Value
Admission to stroke unit	6.0	3.486, 10.325	<0.0001
History of heart failure	0.264	0.146, 0.478	<0.0001
Triglycerides	1.004	1.000, 1.007	0.0365
CTA	0.347	0.205, 0.586	<0.0001
Carotid ultrasonography	0.357	0.219, 0.584	<0.0001
TCD	0.107	0.055, 0.211	<0.0001

CTA = CT angiography, TCD = transcranial Doppler.
Adjustments were made for age, median NIHSS score at admission, atrial fibrillation, diabetes mellitus, hypertension, coronary artery disease, and hyperlipidemia. Results in italics are statistically significant.

with improved patient outcomes up to one year following discharge. Direct comparison of patients with CT based workup to MRI only workup was not possible due to the very small number of patients who had MRI alone. In this cohort, performance of CTA was protective against the primary outcome and death. Previously, a multimodal approach utilizing both noncontrast head CT as well as CT angiography (CTA) with contrast of the head and neck has been shown to identify high risk transient ischemic attach (TIA) and minor stroke patients [22].

These findings may be a reflection of several factors. Patients admitted to Henry Ford Hospital with stroke receive treatments in accordance with Primary Stroke Center certification [10]. At this time, Primary Stroke Center certification requires compliance with eight measures (venous thromboembolism prophylaxis, discharged on antithrombotic therapy, anticoagulation therapy for atrial fibrillation/flutter, thrombolytic therapy, antithrombotic therapy by end of hospital day two, discharged on statin medication, stroke education, and assessed for rehabilitation) [23]. Previously, smoking cessation counseling and dysphagia screening were also included. These variables are known to influence outcome and are not dependent on the acquisition of MRI imaging. A second consideration is that the MRI was performed at a time point where any information provided by the study was too late to act upon in a way that would alter patient outcomes. For this same reason, CTA, which can often be obtained more quickly, may have improved patient outcomes due to more rapid availability of information. Finally, delaying discharge to obtain an MRI may prolong hospitalization, leading to delayed initiation of rehabilitation and increasing the likelihood that patients may develop a hospital acquired infection or other complication that may affect overall outcome.

There are multiple limitations to this study. First, it was a retrospective review of prospectively collected data. Follow-up of patients was limited by what was recorded in the electronic medical record. Patients who sought care at other hospitals or died without notification of the hospital would not have been captured in the electronic medical record. Second, the decision to use CT or MRI was not random. There were baseline differences between groups which may have reflected the decision to do further testing. For example, patients who had CT alone had higher NIHSS scores at admission. This finding may have reflected the fact that clinicians either had no difficulty seeing the infarction on initial CT or preferred not to pursue additional testing with MRI because of the patient's condition. Third, the study was conducted at a single center and was reflective of the practice style of the clinicians who worked there.

In conclusion, this retrospective analysis of a prospectively collected database at a single institution showed that the use of an MRI during hospitalization was not associated with a reduced risk of death, recurrent stroke, or myocardial infarction within one year of follow-up. The results suggest that treatment strategies may not necessarily have been influenced by imaging modality or that changes in treatment strategy based on MRI did not improve outcome. A randomized trial of different imaging modalities should be considered.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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None Declared.

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