

# Early Magnetic Resonance Imaging in Transient Ischemic Attack and Minor Stroke

## Do it or Lose it

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**Background and Purpose**—The use of magnetic resonance imaging (MRI) after transient ischemic attack (TIA) or minor stroke may be affected by the relative timing of imaging. We measured the impact of scanning an individual patient late versus early after TIA and minor stroke.

**Methods**—Two hundred sixty-three TIA or minor stroke (National Institute of Health Stroke Scale score  $\leq 3$ ) patients with a baseline MRI completed within 24 hours of symptom onset and a follow-up MRI at 90 days were included. Baseline and 90-day scans were assessed independently for the presence of any stroke lesions that could explain the presenting symptoms. The presence and pattern of any stroke lesions were compared at the 2 time points.

**Results**—The presence of a stroke (acute or chronic) in any location was more common on baseline MRI versus 90-day MRI (68% vs 56%;  $P=0.005$ ). Thirty percent of subjects with negative scans at 90 days had a clearly identifiable stroke at baseline. When interpreted blinded to the baseline scan, the presumed relevant lesion on the 90-day MR scan was the correct lesion in only 53% patients. One-third (34%) of patients had a different lesion pattern on the baseline scan compared with the 90-day scan. Ninety percent (80/89) of these patients had more lesions on the baseline MRI and 10% (9/89) had new lesions on the 90-day MRI.

**Conclusions**—Delayed MRI after TIA or minor stroke reduces the diagnostic yield and results in missed understanding of the lesion pattern. MRI of minor stroke and TIA patients should occur early after symptom onset, and delayed imaging should be interpreted with caution. (*Stroke*. 2013;44:671-674.)

Brain magnetic resonance imaging (MRI) is the preferred and most sensitive modality after transient ischemic attack (TIA) or minor stroke. It should include diffusion-weighted imaging (DWI) and should be completed within 24 hours of symptom onset<sup>1,2</sup>; its use is 3-fold. The presence of an ischemic lesion in the brain rules in ischemia as the cause of the patient's symptoms. The location and distribution have diagnostic value in relation to the stroke mechanism.<sup>3</sup> Finally, an acute ischemic lesion on DW-MRI in the investigation of TIA and minor stroke has prognostic value as a strong predictor of recurrent stroke.<sup>4-9</sup>

Providing early MRI in all TIA and minor stroke patients may double the use of MRI in this population.<sup>10</sup> In countries with public health care, such as Canada, where magnetic resonance (MR) resources may be limited, identifying the role of early versus late MRI for minor stroke and TIA is important in justifying resource use. In the setting of small ischemic lesions, such as those encountered in TIA and minor stroke, the evolution of the appearance of the lesion on MR sequences

after a few weeks is variable and can include complete reversal, nonspecific hyperintensity on T2-weighted sequences, or clear infarction.<sup>2,11</sup>

We hypothesized that MRI of minor stroke and TIA patients 90 days after their event would show substantially reduced yield as compared with imaging early after the event.

### Methods

Patients were selected from the CT And MRI in the Triage of TIA and Minor Cerebrovascular Events to Identify High Risk Patients (CATCH) Study.<sup>12</sup> CATCH is a prospective cohort study of TIA and minor stroke patients enrolled between April 2008 and September 2010. Consecutive patients aged  $\geq 18$  years presenting with symptoms consistent with a minor stroke, National Institute of Health Stroke Scale (NIHSS)<sup>13</sup> score  $\leq 3$ , or a high-risk TIA (focal weakness or speech disturbance lasting  $>5$  minutes) were referred to the acute stroke team at Foothills Medical Center emergency department and were examined by a stroke neurologist within 24 hours of symptom onset. Exclusion criteria included premonitory modified Rankin scale<sup>14</sup> score  $\geq 2$ , treatment with a thrombolytic drug for this neurological event, or a known serious comorbid illness that would result in the patient being unlikely to survive for 3 months. Detailed baseline

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clinical and outcome information were prospectively collected for each patient. All patients were followed-up for up to 90 days and underwent a computed tomography of the brain and a computed tomography angiography of the head and neck vessel within 24 hours of symptom onset. A subset of patients underwent a brain MRI at baseline and at 90-day follow-up. The selection criteria to be included in this substudy were baseline MRI within 24 hours of symptom onset and follow-up MRI at  $\approx$ 90 days after the presenting event.

### Magnetic Resonance Imaging

All MR images were acquired on a 3.0-T GE scanner. Baseline and follow-up MRI sequences included DWI (slice thickness, 3.5 mm; slice spacing, 0.0 mm), fluid-attenuated inversion recovery, T2, and MR angiography of the intracranial circulation. The 90-day follow-up MRI was jointly interpreted by a neuroradiologist and a stroke neurologist who were blind to the results of the baseline MRI. The raters, who were blind to the baseline MRI, had access to detailed clinical information of the event 90 days before and knew whether a recurrent clinical stroke had occurred after the baseline imaging. In addition, if a lesion qualifying for a chronic stroke on a 90-day MRI was found, then the rater was asked if this stroke was likely to be related to the clinical symptoms of the original event 3 months before. Once the 90-day MRI was interpreted, the baseline MRI was interpreted according to the same criteria. Because the MRI was completed within 24 hours, the lesion was considered related to the presenting symptoms if it showed restricted diffusion. If a stroke was identified on the 90-day MRI that was thought to be the cause of the original symptoms, then this lesion was rated as a true positive if there was a restricted diffusion lesion at the same location on the baseline MRI, and it was rated as a false positive if there was none.

Lesions were classified as acute/subacute or chronic, cortical stroke or subcortical stroke, in the right or left middle cerebral artery, in the right or left anterior cerebral artery, in the right or left posterior cerebral artery, or in the brain stem/cerebellum. Acute/subacute classification required hyperintense signal on DWI with associated hypointensity or isointensity on apparent diffusion coefficient. If a DWI hyperintense lesion also was hyperintense on the apparent diffusion coefficient map, then it was classified as chronic and the DWI hyperintensity was attributed to T2 shine-through phenomenon. Cortical infarct required abnormal signal extending through the cortical ribbon up to the pial surface. Subcortical location was adjudicated otherwise. Chronic subcortical infarcts (without any involvement of the cortex) were required to show evidence of cavitation to differentiate from nonspecific white matter T2 or fluid-attenuated inversion recovery hyperintensities. There was no size threshold for lesions. MR angiography was reviewed for intracranial occlusions and stenosis. The MRI studies were classified according to distribution of lesions in the cortical or subcortical regions of 3 separate vascular territories: right internal carotid artery (right middle cerebral artery and anterior cerebral artery); left internal carotid artery (left middle cerebral artery and anterior cerebral artery); and posterior circulation (right posterior cerebral artery, left posterior cerebral artery, and brain stem/cerebellum). Categories were no definite stroke, single territory cortical stroke, multiple territory cortical strokes, single territory subcortical-only stroke, multiple territory subcortical-only strokes, and multiple strokes in 1 territory, including a cortical stroke. These categories were not mutually exclusive.

### Statistical Analysis

Statistical analysis was completed with Stata (version 11). Standard descriptive statistics were used for continuous or binomial outcomes as appropriate. Proportions of any stroke lesion seen and of lesions that potentially explained the presenting symptoms were compared between the 90-day and the baseline MRIs. The proportion of patients who had a symptomatic lesion correctly identified on 90-day scan was assessed. Distribution of stroke lesions as described above was compared between the 90-day and baseline MRIs.

**Table 1. Baseline Characteristics**

	N=263
Age, y, median (IQR)	69 (13.8)
Sex, men, n (%)	161 (61.5)
TIA: resolved in 24 h, n (%)	137 (52.3)
Baseline NIHSS, median (IQR)	1 (2)
Diabetes mellitus, n (%)	32 (12.2)
Hypertension, n (%)	133 (50.8)
Atrial fibrillation, n (%)	19 (7.3)
Current smoker, n (%)	37 (14.1)
Symptom to baseline imaging, h, median (IQR)	14.9 (11.9)
Time to follow-up imaging, d, median (IQR)	88 (19)

IQR indicates interquartile range; NIHSS, National Institute of Health Stroke Scale; and TIA, transient ischemic attack.

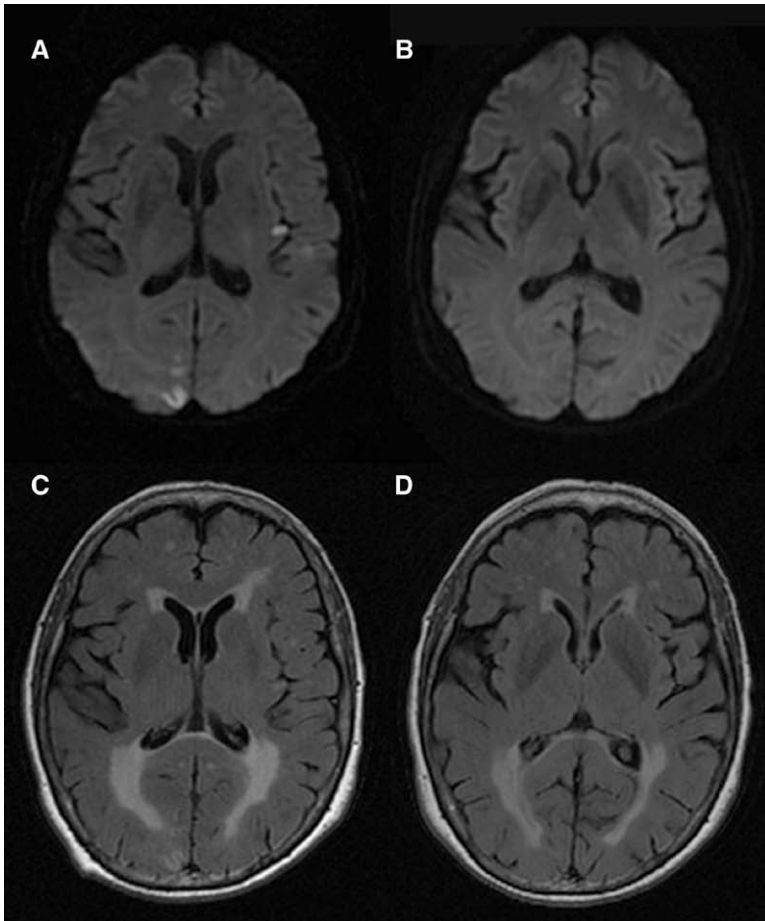
### Results

Two hundred sixty-three patients were included in this study. Baseline characteristics are shown in Table 1. Fifty-two percent (138/263) were TIAs (completely resolved within 24 hours). Stroke at any age in any location was found on 56% (148/263) of the 90-day MRIs and on 68% (179/263) of the baseline MRIs ( $P=0.005$ ). Thirty percent of the negative scans at 90 days had a clearly identifiable stroke on the baseline scan. All of these lesions were acute or subacute DWI lesions on the baseline scan showing nonspecific white matter hyperintensity or no abnormality on the 90-day scan (Table 2 and the Figure). For TIA patients, stroke of any age was found on 42% (58/138) of the 90-day MRIs and on 57% (78/138) of the baseline MRIs ( $P=0.008$ ). For minor stroke, stroke of any age was found on 72% (90/125) of the 90-day MRIs and on 81% (101/125) of the baseline MRIs ( $P=0.05$ ). MR angiography of the intracranial vessels was abnormal on 20% (51/263) of the 90-day MRIs and on 27% (70/263) of the baseline MRIs. In 18 of 19 patients, an occluded artery on baseline MR showed recanalization. Twenty percent (9/46) had clinical recurrent strokes to explain the new lesion, and 80% (37/46) had no identified clinical symptoms. Only 43% (20/46) of all new lesions were identified as a definite stroke lesion on review of the 90-day MRI. The others could be identified only by directly comparing both scans.

In patients with any stroke on 90-day MRI, 70% (104/148) had a least 1 stroke considered likely related to the presenting symptoms based on detailed clinical information. In 53% (78/104) of patients, the correct lesion was identified on the 90-day MRI (true positive). In 13% (13/104) of patients, the stroke lesion identified on the 90-day MRI was not the correct lesion when compared with the baseline MRI. In patients who were DWI-negative at baseline, 89% (105/118) were correctly

**Table 2. Comparison of 90-Day and Baseline Lesion Age**

	90 Days (N=263)	24 Hours (N=263)	P Value
Any stroke	148 (56.2%)	179 (68.0%)	<0.001
Acute/subacute stroke	10 (3.8%)	145 (55.1%)	<0.001
Chronic stroke	144 (54.7%)	78 (29.6%)	<0.001



**Figure.** Transient ischemic attack patient showing cortical acute ischemic lesions in 2 different vascular territories on the baseline imaging completed within 24 hours of symptom onset on diffusion-weighted imaging (DWI) (A) and fluid-attenuated inversion recovery (FLAIR) (C) sequences. Follow-up imaging of the same patient 90 days later did not show a convincing stroke lesion in the corresponding gyri on either the DWI (B) or the FLAIR (D) sequences.

identified as having no culprit lesion on the 90-day MRI, and in 11% (13/118) of patients an incorrect lesion was identified on the 90-day MRI (false positive).

One-third (89/263) of patients had a different lesion distribution on the baseline MRI as compared with the 90-day MRI. Ninety percent (80/89) of these patients had more lesions on the baseline MRI and 10% (9/89) had new lesions on the 90-day MRI. The main difference observed was that patients with multiple DWI lesions on the baseline scan showed either no lesion or only a single lesion on the 90-day MRI (Table 3).

**Table 3. Comparison of Stroke Lesion Distribution Between Baseline and 90-Day Magnetic Resonance Imaging Scans**

Distribution Category	Baseline MRI, n/N (%)	90-Day MRI, n/N (%)	P Value
No stroke	84/263 (32)	115/263 (44)	0.005
Single cortical stroke	24/263 (9)	40/263 (15)	0.030
Multiple territory cortical strokes	21/263 (8)	17/263 (6)	0.500
Single subcortical stroke (no cortical stroke)	41/263 (16)	44/263 (17)	0.700
Multiple territory subcortical strokes (no cortical stroke)	12/263 (5)	11/263 (4)	0.830
Multiple strokes in 1 territory, including 1 cortical	81/263 (31)	36/263 (14)	<0.001

Any age (acute, subacute, or chronic) of stroke lesion is included in this comparison. MRI indicates magnetic resonance imaging.

### Discussion

The timing of brain MRI after a TIA or minor stroke greatly affects its diagnostic use. Compared with an MRI completed within 24 hours of the symptom onset, an MRI completed 90 days later frequently misses the symptomatic lesion. The radiological diagnosis of stroke is frequently missed, and even if a stroke lesion can be identified, the distribution of lesions among vascular territories has changed as compared with the baseline scan. When there is an identifiable stroke lesion on late MRI, it is often difficult to definitively relate it to the original presenting symptoms.

DWI hyperintense lesions are common after TIA and minor stroke,<sup>9,15,16</sup> but the hyperintensity on DWI is also known to decrease in intensity after 10 days<sup>17</sup> and disappear altogether from 2 to 3 weeks after the original event.<sup>11,18</sup> One group showed that DWI adds relevant information to T2 imaging alone in the investigation of TIA or minor stroke if completed as late as 2 to 3 weeks after the event.<sup>18</sup> The main explanation for these discrepancies is the disappearance of DWI-positive lesions that evolve into nonspecific white matter fluid-attenuated inversion recovery hyperintensities and DWI reversal. DWI reversal is uncommon in large strokes<sup>19</sup> but is much more frequent for the small DWI lesions encountered in TIA and minor stroke.<sup>20</sup> When these lesions do persist, they frequently lead to a nonspecific, small, hyperintense signal in a subcortical area without evidence of cavitation. On a blind reading of a 90-day scan, which is equivalent to ordering a scan in a delayed

setting as an outpatient, these lesions cannot be identified as the symptomatic lesion because they are not different from nonspecific background T2 hyperintense lesions.

There is poor agreement even among experts on the clinical diagnosis of TIA,<sup>21,22</sup> and a DWI lesion resolves this issue by confirming the diagnosis of ischemia. DWI lesions also have prognostic value, particularly in TIA and minor stroke.<sup>9</sup> The correlation of the clinical diagnosis of the vascular territory with the DWI abnormality is only moderate in TIA and minor stroke.<sup>23</sup> Lesion distribution patterns also may provide a clue to the underlying cause. For example, multiple DWI lesions in multiple vascular territories may indicate a cardiac or aortic source for the event, and distribution of single carotid lesions in combination with a severe ipsilateral carotid stenosis implicates that carotid stenosis as symptomatic.

A limitation to this study is the development of new lesions (symptomatic or asymptomatic) between the first and the second scan. Only 20 such lesions were clearly identified blindly on the 90-day scan. These new lesions had the opposite effect of increasing diagnostic yield of the delayed scan and represent a failure of poststroke secondary preventive therapy. It is possible that some small lesions were missed because of slice thickness, but we use 3.5-mm-thin slices with no interslice gap to minimize this potential artifact. Our analysis represents a best-case scenario in which the scans were read by a stroke neurologist and neuroradiologist together with access to detailed clinical information. This provided high sensitivity for even small stroke lesions. In real life, clinical information available to a neuroradiologist may often be minimal, and MRI reports are frequently limited to the assessment of acute or subacute changes or obvious large chronic stroke lesions. We believe that our interpretation of the 90-day scan likely has a higher yield than a delayed interpretation completed in everyday practice, in which the clinical details are frequently missing.

In conclusion, early MRI scanning provides better sensitivity to identify stroke lesions and shows different lesion topography than delayed MRI after TIA or minor stroke. The results of this study support current guidelines<sup>1</sup> and call for resource allocation to provide access to early MRI in the setting of TIA and minor stroke. This study also suggests that late MRI must be interpreted with caution because the absence of abnormality does not guarantee the absence of pathology.

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