# Detectability of Ischemic Lesions on Diffusion-Weighted Imaging Is Biphasic after Transient Ischemic Attack

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*Background:* Experimental studies of transient focal ischemia indicate biphasic detectability of lesions by diffusion-weighted imaging (DWI); poorly detectable phase exists at 1-12 hours after reperfusion. The present study aimed to clarify whether poorly detectable phase also exists in DWI of transient ischemic attack (TIA) patients. *Methods:* A retrospective study was conducted in 144 consecutive TIA patients who underwent magnetic resonance imaging (MRI) within 2 weeks after carotid TIA. Patients were classified into 9 groups according to time from disappearance of TIA symptoms to DWI: intraischemic period, 0-1 hour, 1-12 hours, 12-24 hours, 1-2 days, 2-3 days, 3-7 days, 7-10 days, and 10-14 days after the end of TIA. *Results:* Lesions were detected in 33 of 144 patients (22.9%). The frequency of positive lesions was 20% in the intraischemic period and 30.8% at 0-1 hour after the end of TIA; it markedly decreased to 8.7% at 1-12 hours after end of TIA. Thereafter, it increased to 21.7%, 30.8%, 36.4%, 37.0%, 38.5%, and 30% at 12-24 hours, 1-2 days, 2-3 days, 3-7 days, 7-10 days, and 10-14 days after the end of TIA, respectively. In 7 patients, MRI was repeated twice, at 1-12 hours and then at 5-13 days after the end of TIA. Lesions were never detected on the first MRI but were clearly demonstrated in 4 of 7 patients on the second MRI. *Conclusions:* The detectability of ischemic lesions may be biphasic after TIA as indicated by experimental studies. **Key Words:** Diffusion-weighted imaging—transient ischemic attack—refractory phase—detectability.


## Introduction

Since the recent development of magnetic resonance imaging (MRI), MRI findings have been included into the diagnostic criteria of several brain diseases, including transient ischemic attack (TIA). Conventionally, TIA has been defined as neurologic symptoms of vascular etiology that resolve within 24 hours. After the accumulation of clinical knowledge for many years, the TIA Working Group in the United States proposed a new definition in 2002 that ischemic cerebral symptoms in TIA should typically last for less than 1 hour and should not be accompanied by evidence of acute infarction.[1] Easton et al[2] proposed a more advanced definition in 2009 that a transient episode of neurologic dysfunction caused by focal brain, spinal cord, or retinal ischemia should not be accompanied by acute infarction. These definitions

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recommend that TIA patients should undergo neuroimaging evaluation within 24 hours after symptom onset, preferably with diffusion-weighted imaging (DWI) sequences to exclude acute infarction.

Experimental studies have repeatedly indicated that the apparent diffusion coefficient (ADC) significantly decreases within minutes after the onset of cerebral ischemia.[3,4] Interestingly, several experimental studies using transient focal ischemic models have shown that in ischemic areas with sufficient ADC reduction, ADC completely recovers at 1 hour after reperfusion and thereafter decreases at 12-48 hours after reperfusion, leading to cerebral infarction.[5-7] These experimental findings appear to indicate that on DWI in transiently ischemic patients, ischemic lesions do not appear in the initial hours after reperfusion and then begin to appear thereafter. Unfortunately, however, previous MRI studies in TIA patients have not rigorously investigated lesion detectability during the early hours after reperfusion. Therefore, in the present retrospective study, we attempted to determine whether a DWI refractory period exists after the disappearance of ischemic symptoms (the end of TIA) in TIA patients.

## Subjects and Methods

### *Design*

The diagnosis of TIA was based on the concept that focal neurologic symptoms suddenly develop and disappear within 24 hours, irrespective of the MRI findings. In total, 144 consecutive TIA patients who were admitted to our hospital from May 1998 to March 2009 were retrospectively studied. MRI had been performed in all the patients during the TIA symptomatic period or 0-14 days after the disappearance of symptoms. TIA in the vertebral artery territory was excluded from the study because the onset and end of symptoms are often obscure in vertebral TIA. Patients with isolated amaurosis fugax were also excluded. This study was approved by the institutional ethics committee.

Age, sex, duration of symptoms, history of TIA and/or stroke, and vascular risk factors (hypertension, diabetes, hyperlipidemia, and smoking) were documented in all patients. We classified the patients into 9 groups according to the time from the end of TIA to DWI instead of the time from the onset of TIA to DWI. The end of TIA symptoms was regarded as the time of reperfusion. The reason for choosing such a time classification was to compare the present results with the experimental findings. DWI studies had been performed during the symptomatic period (−0 hours), 0-1 hour, 1-12 hours, 12-24 hours, 1-2 days, 2-3 days, 3-7 days, 7-10 days, and 10-14 days after the end of TIA. The early period was precisely divided into groups such as 0-1 hour, 1-12 hours, 12-24 hours, and 1-2 days after the end of TIA because ADC has been reported to completely recover at 1 hour after reperfusion[5-7] and to again decrease at 12 hours,[5] 24 hours,[6] or 48 hours[7] after reperfusion in experimental studies of transient focal cerebral ischemia.

### *Magnetic Resonance Imaging*

MRI was performed using a 1.5 T (Siemens MAGNETOM Vision or MAGNETOM Sonata scanner; Erlangen, Germany). DWI scanning was performed using a single-shot, multi-slice, spin-echo, echo-planar imaging sequence. The following DWI parameters were used: echo time (TE), 123 milliseconds; field of view, 23 × 23 cm; matrix, 128 × 200; slice thickness, 4 mm; and interslice gap, 2 mm. Diffusion gradients were applied in the through-plane direction with a b value of 1100 seconds/mm$^2$. Since 1999, the DWI parameters were changed to TE, 100 milliseconds; matrix, 98 × 128. Diffusion gradients were applied in each of the x, y, and z directions, with b values of 1000 seconds/mm$^2$, and the trace image was calculated. Conventional MRI studies included T1-weighted (repetition time [TR]/TE, 630/14C) and T2-weighted (TR/TE, 5400/99) images, and fluid-attenuation inversion recovery (TR/TE/inversion time, 9000/105/2400) images were obtained if required. Radiologic evaluation was performed by mutual agreement between the neurologists and radiologists. ADC values were not calculated because of the small size of the lesions. The MRI studies were repeated in 22 patients, 11 of whom underwent the first DWI within 12 hours after the disappearance of TIA symptoms.

### *Statistical Analysis*

Analysis of variance and $\chi^2$ tests were used to compare the mean values and frequencies according to the presence and the absence of lesions.

Each group as classified previously was compared using 1-way factorial analysis of variance. $\chi^2$ test was used to examine differences with the frequency of positive lesions between 1-12–hour group and the other groups. All statistical analyses were performed by using the SAS statistical software package (release version 8.2; SAS Institute, Cary, NC). Results were considered significant at $P$ less than .05.

## Results

In total, 144 TIA patients (means ± standard deviation age, 69.3 ± 10.3 years; 102 men [70.8%]) were admitted to our hospital. An initial DWI MRI revealed ischemic lesions in 33 of 144 patients (22.9%). There were no significant differences in the baseline characteristics and vascular risk factors between the patients with lesions and those without lesions, although TIA history tended to be more common in the lesion-negative patients than that in the lesion-positive patients (Table 1).