

Transient seizure activity demonstrated by Tc-99m HMPAO SPECT and diffusion-weighted MR imaging

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Cerebral perfusion single photon emission computed tomography (SPECT) has been used to confirm the localization of the epileptic focus and the evaluation of seizure. Recently, diffusion-weighted MR imaging (DWI) has been recognized for evaluation of seizure activity. We describe a case of transient seizure activity demonstrated by Tc-99m HMPAO SPECT and DWI. This patient was a 61-year-old woman with a 10-month history of right middle cerebral artery (MCA) infarction who had a generalized seizure during MRI. DWI immediately after seizure showed transient hyperintensity in the right frontal gray matter and the white matter, and these apparent diffusion coefficients (ADC) were transiently decreased. This transient hyperintensity on DWI corresponded to transient hyperperfusion identifying the epileptic focus on interictal Tc-99m HMPAO SPECT. Transient sustained seizure activity might cause these changes on DWI and SPECT. It was considered that interictal Tc-99m HMPAO SPECT showed the delayed hyperperfusion caused by excitatory neuronal overaction and DWI showed cytotoxic edema seizure-induced by energy failure of the membrane-bound Na/K-ATPase pump.

Key words: seizure activity, epilepsy, diffusion-weighted MR imaging, technetium-99m hexamethylpropyleneamine oxime (Tc-99m HMPAO), single photon emission computed tomography (SPECT)

INTRODUCTION

IN EPILEPSY, it is known that cerebral perfusion single photon emission computed tomography (SPECT) is very useful for evaluation and localization of the epileptic focus.^{1,2} The usefulness of diffusion-weighted MR imaging (DWI) for epilepsy was recently reported, and it has been recognized for the evaluation of seizure activity.^{3–6} DWI is a sensitive method for assessing the molecular motion of water. The extent of water diffusion *in vivo* is determined as the apparent diffusion coefficient (ADC). A decrease in ADC is seen in regions of restricted water diffusion, which appears as hyperintensity on DWI. DWI has become an essential tool for making a diagnosis of acute cerebral ischemia or infarction.⁷ In this report we

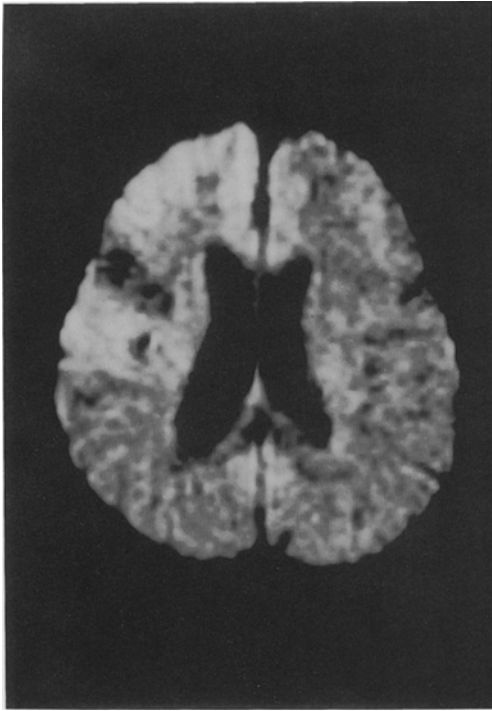
describe a case of transient seizure activity demonstrated clearly by technetium-99m hexamethylpropyleneamine oxime (Tc-99m HMPAO) SPECT and DWI.

CASE REPORT

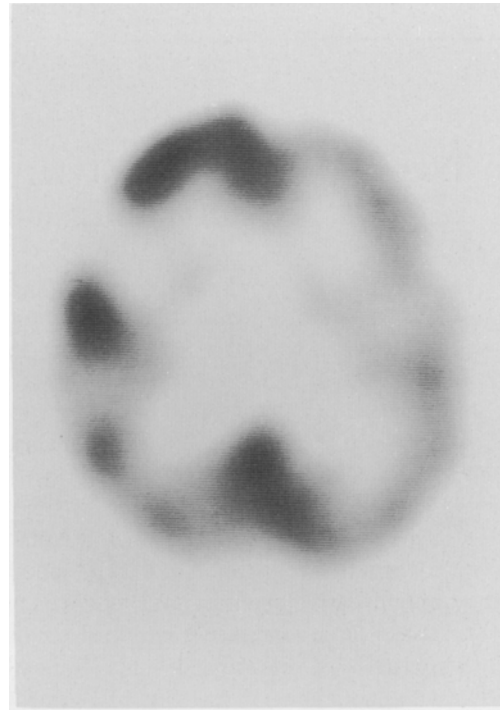
This patient was a 61-year-old woman who had a 10-month history of mild left hemiparesis due to cerebral infarction in the right middle cerebral artery (MCA) territory. On January 24, 2000, she noticed left-sided facial spasms, which continued for more than 1 hour, so she was transported to our hospital by ambulance. On admission, she was alert and well oriented. She had a simple partial seizure in the left face. Her simple partial seizure was controlled by administration of diazepam intravenously. 3 hours later, MRI was performed on a 1.5 T (Signa Horizon Lx, GE-Yokogawa Medical Co., Tokyo). During MRI, she suddenly had a generalized seizure. The seizure subsided within a few minutes without further anticonvulsant therapy. Immediately after the

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A



B

Fig. 1 A 61-year-old woman with a 10-month history of right middle cerebral artery (MCA) infarction has symptomatic epilepsy. (A) Diffusion-weighted MR imaging (TR/TE/EC 10000/99/1, 5-mm section thickness, b-value of 1000 s/mm², three directions) immediately after the seizure shows hyperintensity in the right frontal gray matter and in the white matter around an old infarction of the right MCA territory. (B) Tc-99m HMPAO SPECT (740 MBq) in the interictal state shows hyperperfusion in the right frontal cortex. The regional cerebral blood flow of old infarction in the right MCA territory is observed as severe hypoperfusion.

seizure ceased, DWI showed hyperintensity in the right frontal gray matter and slight hyperintensity in the white matter around an old cerebral infarction in the right MCA territory (Fig. 1A). Fluid-attenuated inversion recovery (FLAIR) images showed no acute cerebral infarction. After MRI, a generalized seizure occurred again. Although the generalized seizure was controlled by administration of diazepam intravenously, she had disturbance of consciousness for approximately 5 hours. Nine hours later she again became alert, cerebral perfusion SPECT was obtained. SPECT was performed 5 minutes after intravenous injection of Tc-99m HMPAO (740 MBq). We used a gamma camera (Starcam 400AC/T, GE-Yokogawa Medical Co., Tokyo) equipped with a low-energy all-purpose collimator, and collected data under the following conditions: 128 × 128 matrix, 360°, 64 directions, and 35 seconds per direction. During reconstruction of SPECT images, a Butterworth filter and a Ramp filter were used for preprocessing and post-processing, respectively. Interictal Tc-99m HMPAO SPECT showed significant hyperperfusion in the right frontal cortex and hypoperfusion in the region of old infarction in the right MCA territory (Fig. 1B). Electro-

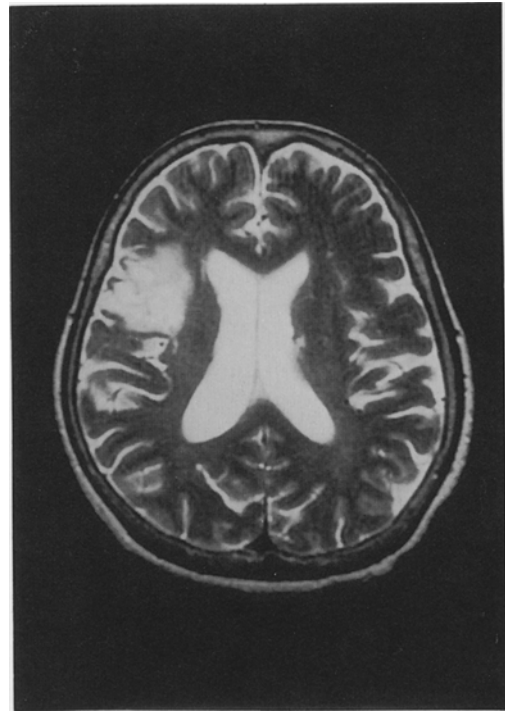
encephalography 24 hours after seizure onset showed no seizure discharges or waves. Thereafter, she had no epileptic episode. MRI and Tc-99m HMPAO SPECT were repeated 8 days later. On DWI, the abnormalities in the right frontal gray matter and white matter around the old infarction in the right MCA territory had returned to normal intensity (Fig. 2A). T2-weighted MR and FLAIR images showed no evidence of acute cerebral infarction (Fig. 2B, C). On Tc-99m HMPAO SPECT, hyperperfusion in the right frontal cortex had returned to the baseline (Fig. 2D). On the basis of her clinical course, DWI and SPECT findings, it was suggested that she had symptomatic epilepsy due to old cerebral infarction in the right MCA territory and her epileptic focus was in the right frontal lobe.

DISCUSSION

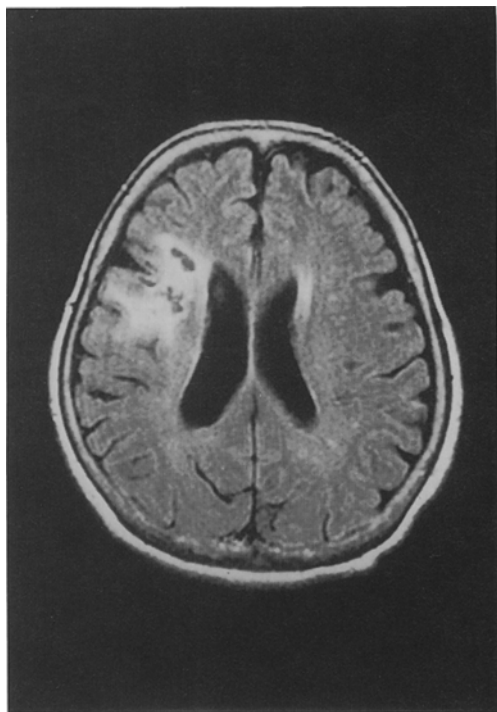
Cerebral perfusion SPECT is a useful method for evaluating the change in regional cerebral blood flow (CBF) in a seizure. Ictal SPECT shows hyperperfusion and interictal SPECT shows hypoperfusion or no changes in the epileptic focus.^{1,2} Although it is known that postictal CBF



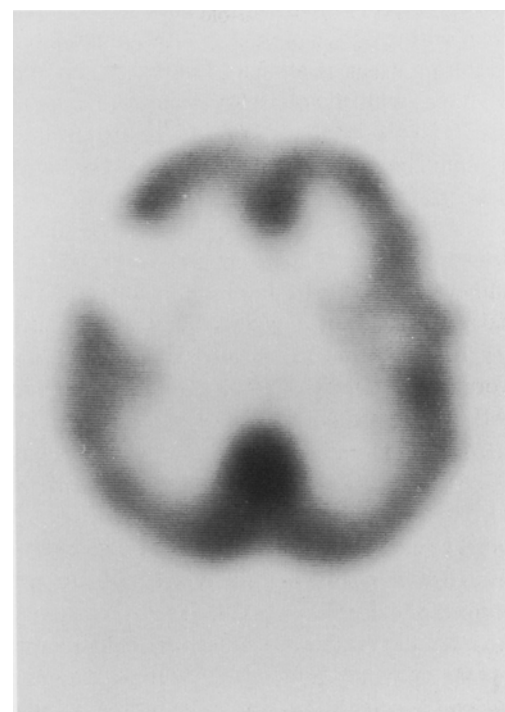
A



B



C



D

Fig. 2 MRI and Tc-99m HMPAO SPECT (740 MBq) 8 days later. (A) The abnormalities on diffusion-weighted MR imaging (TR/TE/EC 10000/99/1, 5-mm section thickness, b-value of 1000 s/mm², three directions) in the right frontal gray matter and in the white matter around an old infarction in the right MCA territory have returned to normal intensity. (B and C) T2-weighted MR (TR/TE/EC 4000/105/2) (B) and fluid-attenuated inversion recovery (TR/TE/EC/TI 8000/112/1/1800) (C) show no evidence of acute cerebral infarction in the right frontal gray matter and in the white matter around an old infarction in the right MCA territory. (D) Interictal Tc-99m HMPAO SPECT (740 MBq) shows that the hyperperfusion in the right frontal cortex has returned to the baseline.

changes return to the baseline within 10–30 min after seizure,⁸ postictal and interictal hyperperfusion in the epileptic focus has been reported in SPECT^{9,10} or PET¹¹ studies. In the present case, interictal Tc-99m HMPAO SPECT also showed transient hyper-perfusion in the right frontal cortex. CBF in the right frontal cortex was a transient increase of approximately 41% compared with CBF in the left frontal cortex. The interictal hyperperfused phenomenon in the epileptic focus might be considered to be sustained seizure activity because interictal hyperperfusion was transient and the patient had no neurological deficit in this episode, but the mechanism of hyperperfusion in the postictal or interictal state has not been clarified.¹¹

Changes in water diffusion in status epilepticus with DWI has been reported by investigators. The epileptic focus will appear as hyperintensity on DWI and there will be a decrease in ADC. In a model of bicuculline-induced status epilepticus in rats, Zhong et al.³ reported that the reduction in ADC was approximately 14–18% within 3 hours after injection of the drug. In experimental model of kainic acid-induced status epilepticus in rats, Righini A et al.⁴ reported that the reduction in ADC was approximately 36–49%, and reached a peak 24 hours after intraperitoneal kainic acid injection. In man, Wiesmann et al.⁵ reported a patient with a 27% decrease in ADC in the left motor cortex during status epilepticus. Lansberg et al.⁶ reported three patients with complex partial status epilepticus who had a mean 36% decrease in ADC. In the present case, DWI immediately after seizure showed hyperintensity in the right frontal gray matter and white matter around an old infarction in the right MCA territory. The ADC in the gray matter decreased approximately 21%, and ADC in the white matter decreased approximately 10%, respectively, compared with the contralateral cerebral hemisphere. It is said that in a seizure energy failure of the membrane-bound Na/K-ATPase pump caused by excitatory neuronal overaction^{12,13} leads to cytotoxic edema induced by an influx of extracellular water and Na⁺ into the cells¹³ and shrinkage of the extracellular space with an high K⁺.¹⁴ We suggest that the decrease in ADC in sustained seizure activity was caused by cytotoxic edema associated with excitatory neuronal overaction.⁶ The mechanism of a decrease in ADC in seizure activity may be considered to differ from that in acute cerebral ischemia or infarction, because cytotoxic edema in ischemic stroke was caused by energy failure of the membrane-bound Na/K-ATPase pump associated with a reduction in CBF.

From our SPECT and DWI findings, we considered that a transient hyperperfusion and hyperintensity in the right frontal gray matter might be associated with excitatory neuronal overaction. SPECT is useful for the localization and evaluation of CBF changes caused by excitatory neuronal overaction in the ictal, postictal or interictal state. DWI may be useful for evaluating seizure-induced

cytotoxic edema caused by seizure activity. The repeated cytotoxic edema induced by seizure activity may lead to chronic hypofunction in the epileptic focus or intractable epilepsy.

In conclusion, it is very important to understand the condition of the nerve cells and its effect on seizure activity. In this case we could not obtain SPECT and DWI at the same time. To clarify the pathology of seizures, it will be important and necessary to compare cerebral perfusion SPECT findings with DWI findings. Therefore, if possible, SPECT and DWI should be done at the same time.

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