Original article

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The origin of the focal spike in musicogenic epilepsy

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ABSTRACT – To clarify the pathogenesis of a typical case of musicogenic epilepsy, we examined interictal spikes using the dipole tracing method (DTM). The patient was a 49-year-old, right-handed Japanese man. He first experienced seizures at the age of 32 years; listening to his favorite piece of music frequently triggered them. His seizure type is partial (often complex, but sometimes simple). An interictal EEG examination revealed many focal spikes in F8 and T4. We estimated equivalent current dipoles (ECDs) using DTM. We performed one-dipole analyses on the peaks of the spikes using an EEG analyzer with a three-layer head model called the scalp-skull-brain (SSB) model. We analyzed the interictal EEG because there were no spikes during the seizure. The ECDs were located in the posterior transverse temporal gyrus. The characteristics in this patient not only bolstered arguments in favor of the role of the right temporal lobe in musicogenic epilepsy, but also showed that transverse temporal gyri, which are included in the auditory area, could play an important role in musicogenic epilepsy.
[Published with video sequences].

Keywords: musicogenic epilepsy, transverse temporal gyrus, dipole tracing method

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Musicogenic epilepsy, named by Critchley (Critchley 1937), is a rare form of reflex epilepsy characterized by epileptic seizures triggered by music, that develops during middle age and is of uncertain cause (Kawai *et al*. 1978). Ictal SPECT studies of musicogenic epilepsy (Wieser *et al*. 1997, Genc *et al*. 2001, Gelisse *et al*. 2003) have demonstrated right anterior and mesial temporal hyperperfusion, but spatial resolution is not always accurate in SPECT.

There are many brain mapping methods, based on the equivalent current dipole (ECD), which may be used to estimate the location of the electrical source. Most methods use a standardized model of the head, but some brain mapping methods developed in recent years, use realistic head models (Roth *et al*. 1993, Homma *et al*. 1994, Cuffin 1995, Yvert *et al*. 1996), which improve accuracy. We have already shown the accuracy of the dipole tracing method (DTM) in epileptic patients (Shibata *et al*. 1998).

To clarify the pathogenesis of a typical case of musicogenic epilepsy, we examined the interictal spikes using the dipole tracing method (DTM).

Case report

The patient was a 49-year-old, right-handed Japanese man who was a music lover. His parents, his prenatal development, birth, childhood and juvenile history were all unremarkable. His seizures, which began at the age of 32 years, are frequently triggered by listening to his favorite music. During seizures, he feels swallowed up into the music and sees flashes of peaceful countryside that he has never actually seen. He is unable to hear anything and feels fearful. The seizures last for about 30 to 40 seconds, during which time he maintains consciousness and is aware of his surroundings and is able to act freely. The seizures occur several times a week. Rarely, the seizures continue for one or two minutes, which affect his consciousness. His head aches afterwards. The piece of music that induces the seizures is his favorite one, Kureruomoi by the Sadistic Mica Band, which he listened to often. No other music has ever provoked a seizure.

He had a seizure five years ago while driving with his wife and listening to Kureruomoi. He almost lost consciousness. His wife assumed him to be ill and recommended that he consult a doctor. An EEG examination revealed an abnormality, so he was given 400 mg of valproic acid. The seizure frequency slightly decreased. He was referred to our hospital for a more detailed examination.

Neurological, laboratory, brain MR and interictal SPECT examinations revealed no abnormal findings in our hospital. Interictal EEG examinations showed many focal spikes in F8 and T4 (*figure 1*). The patient experienced a seizure during the simultaneous video EEG recording while listening to the music that induces his seizures. This seizure is presented on the video. The seizure frequency decreased remarkably as a consequence of treatment with additional anticonvulsants.

Methods

We recorded an EEG using 21 electrodes arranged according to the international 10-20 system. The reference electrode was placed on his left ear. We recorded the EEGs using a digital EEG recorder (EEG-2110; Nihon-Koden Co. Ltd., Japan) at a sampling time of 1 msec. We performed one-dipole analyses on the peaks of the spikes using an EEG analyzer (CDT1000; Chuo Electronics Co. Ltd., Tokyo, Japan), with a three-layer head model called the scalp-skull-brain (SSB) model (Homma, *et al.* 1994). We estimated dipoles of the same spikes at five consecutive time points with an interval of 1 msec. To create an SSB model, horizontal slices produced by X-ray computed tomography (CT), at 5 mm intervals were scanned, and the surface of the scalp and the outer and inner contours of the skull were delineated.

The surface of the scalp to the outside of the skull was designated the scalp layer; the outside of the skull to the inside of the skull, the skull layer; and inside the skull, the

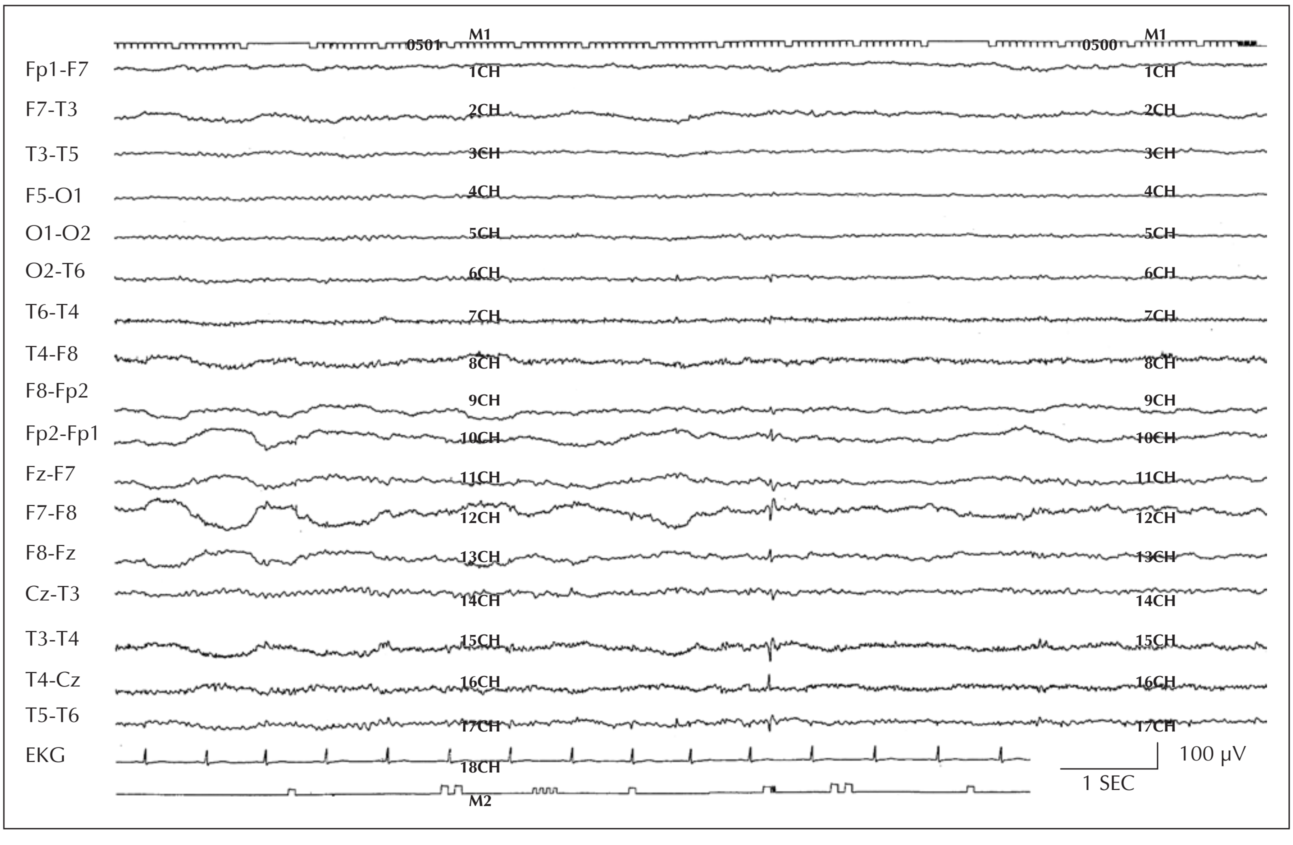

Figure 1. Example of a focal spike maximal over F8, T4.

brain layer. The ratio of the electric conductivity of the layers was calculated as 1:1/80:1. The equivalent current dipoles (ECDs) were computed as vectors on the coordinates of a 3-dimensional model of the head. Only ECDs in which dipolarity was 98% or more were adopted and marked on the appropriate slice of the CT images.

Results

We estimated ECDs using interictal EEG, because there were no spikes during the seizure. *Figure 2* shows the horizontal view of results of DTM. In order to clarify the anatomical locations of these results, we marked the locations of the ECDs with small red squares on the appropriate slice of the CT images (*figure 3*). They were located in the posterior transverse temporal gyrus. In *figure 4*, we show them more clearly as a schematic illustration.

Discussion

We believe that this patient has musicogenic epilepsy, because his seizures occur when he listens to a specific song and because of the presence of focal spikes. He actually experienced an epileptic seizure, triggered by the music, during the simultaneous video EEG recording.

Usually, musicogenic epilepsy seizures are partial (often complex, but sometimes simple) or secondary generalized tonic-clonic. EEG examinations usually reveal epileptiform abnormalities of the temporal lobe, especially in right-side dominance (Wieser 1997). Our patient had partial epilepsy focused on the temporal lobe. Reports indicate that in most patients the role of music as a trigger is neither exclusive nor specific, that seizures often occur spontaneously, and that the musical specificity varies. However, in typical musicogenic epilepsy, triggers are quite specific, such as listening to, or playing, a particular piece of music (Avanzini 2003). The clinical characteristics in this patient indicate typical musicogenic epilepsy.

Penfield and Perot reported a tendency for lateralization of musical hallucinations as experiential responses in the right temporal lobe during electrical brain stimulation (Penfield and Perot 1963). Musical abilities, such as singing or playing in tune, recognizing tunes and keeping rhythm, may be selectively incapacitated by pathogenic lesions of either temporal lobe, but mainly the right, and

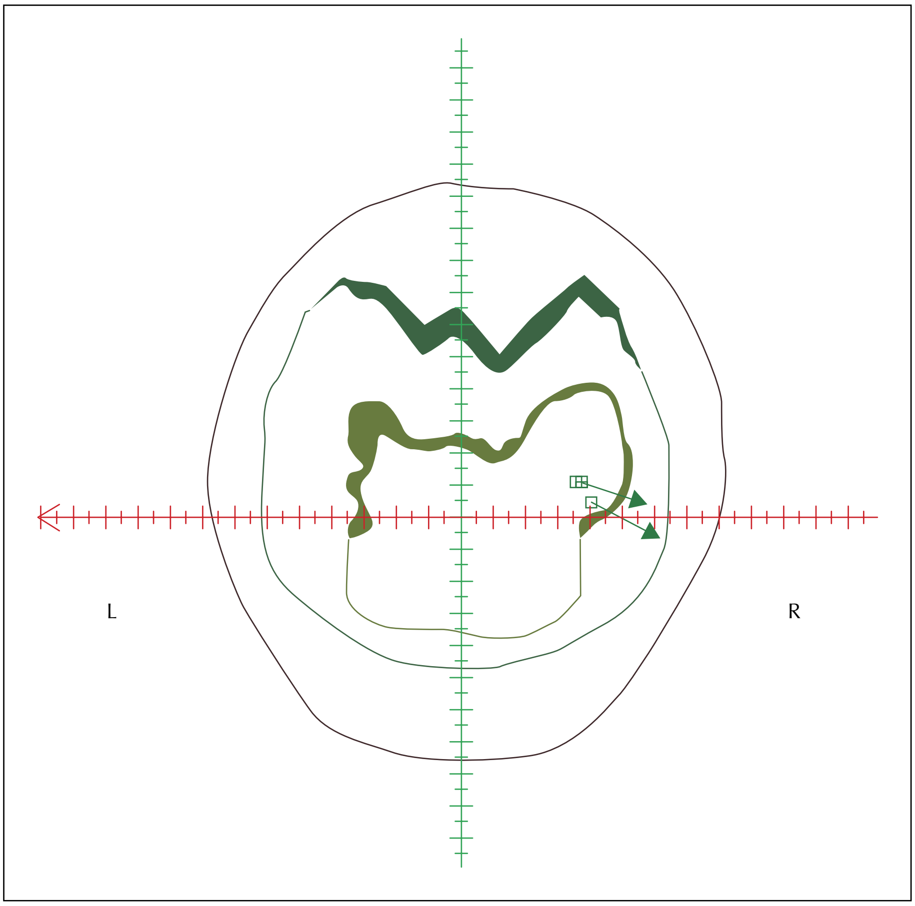

Figure 2. Results of dipole tracing method applied to focal spike. The arrows show the locations and orientations of ECDs in the horizontal view.

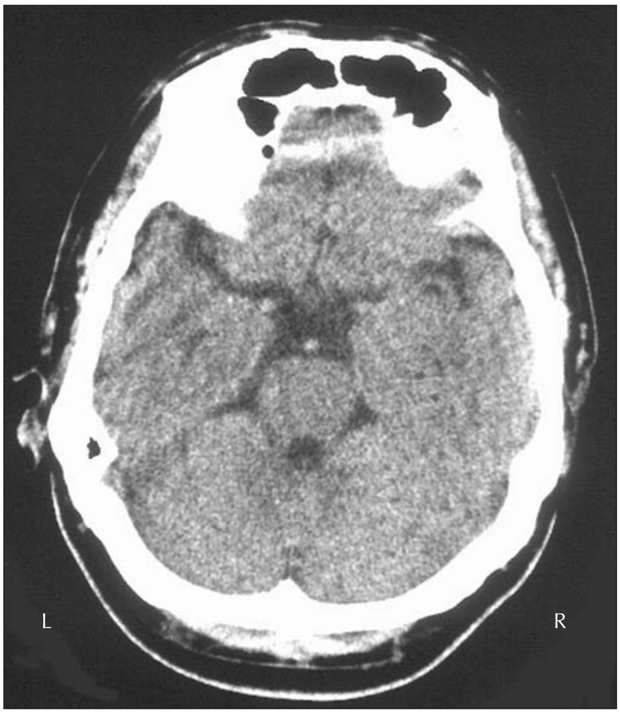

Figure 3. The locations of ECDs marked with small red squares on the CT image. They were located in the posterior transverse temporal gyrus.

have been more often described in association with temporal lobe lesions in the right side rather than in the left side. Wieser *et al.* performed a brain SPECT in a 32-year-old woman with musicogenic epilepsy showing slight hyper-perfusion in the right temporal lobe (Wieser *et al.* 1997). The epileptogenic focus of previous studies has been much more prevalent in the right temporal lobe than in the left. Taken together, these data indicate that the pathogenesis of musicogenic epilepsy is in the right temporal lobe.

The auditory association area may be divided into functional areas such as areas related to monotones, chords, consonances, melodies and music. Each area has a qualitatively different neuron group. However, the precise function of the auditory area is unclear. The characteristics in this patient not only bolstered arguments in favor of the role of the right temporal lobe in musicogenic epilepsy, but also showed the importance of transverse temporal gyri, which are included in the auditory area. Transverse temporal gyri could play an important role in musicogenic epilepsy. □

Legend for video sequences

We show the state of the patient from one minute after the music started. Firstly, rapid blinking appeared, then he began to experience an experiential phenomenon. There were however, no changes on the EEG. About two minutes later after the music started, slow waves were detected. Soon, the voltage of the waves was higher and the frequency decreased, then the waves disappeared and the seizure stopped. The changes in the slow waves confirmed the occurrence of an epileptic seizure.

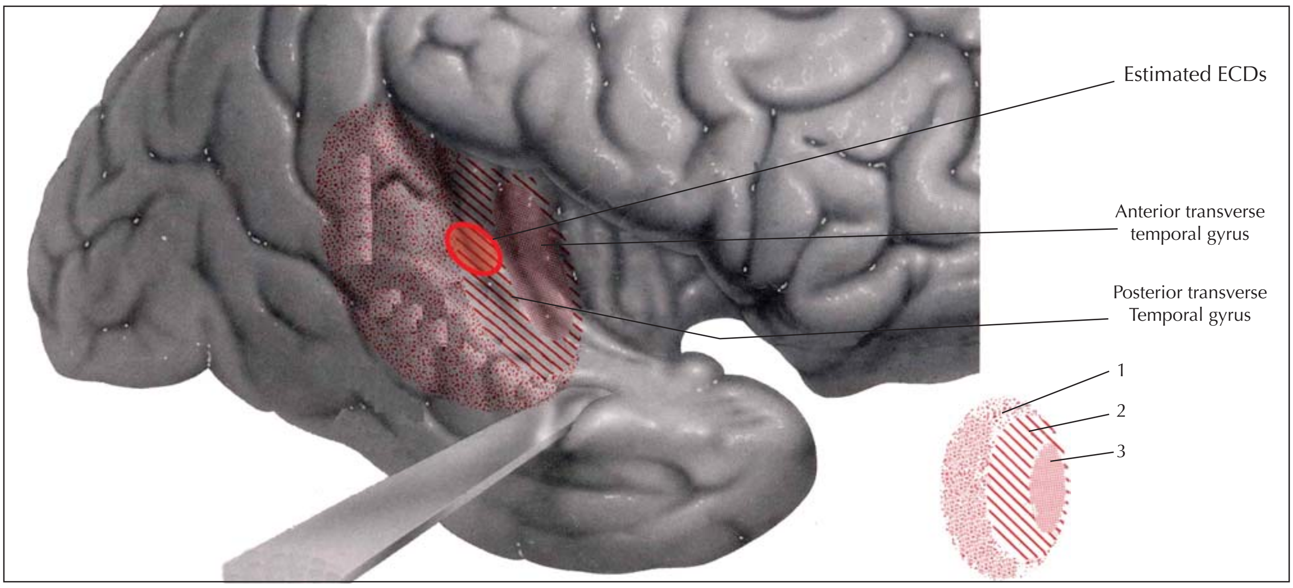

Figure 4. Schematic illustration of temporal lobe anatomy with the locations of ECDs: 1. Wernicke area, 2. The auditory association cortex, 3. The primary auditory cortex (partial interpolation from Takenobu *et al.* 1996).

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