Mid-Temporal Spikes in Childhood EEGs and the Hippocampus

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ICHIOH, S. Mid-Temporal Spikes in Childhood EEGs and the Hippocampus. Tohoku J. Exp. Med., 1990, 161, Suppl., 241-251 — In benign childhood epilepsy, EEGs often show spikes in the mid-temporal region although there is no evidence of brain lesions in this region. In this study, mid-temporal spikes are classified into four types with regard to scalp distribution, and it is hypothesized that these spikes may originate in the hippocampus and then spread to the scalp, mainly by volume conduction. The subjects were 50 children (epileptic and non-epileptic), 2 to 15 years of age, with mid-temporal spikes in EEGs: type 1, unilateral mid-temporal spikes (25 cases); type 2, bilateral synchronous spikes (8 cases); type 3, bilateral synchronous spikes with the two sides having opposite polarities (2 cases); and type 4, bilateral asynchronous spikes (15 cases). Because the pyramidal cells are arranged in the form of a "C" in transverse sections of the hippocampus, scalp distribution of spikes might be explained as follows. If the axis of electrical dipoles in the hippocampus is oblique, the electrical potential will spread unilaterally; if the axis is vertical, the potential will spread bilaterally; if the axis is horizontal, the two sides will have opposite poles. With regard to bilateral asynchronous spikes, the two hippocampi may be involved in generation of the spikes. It is thought that the mid-temporal spikes may be non-specific phenomena resulting from various etiologies. ——— benign childhood epilepsy; mid-temporal spikes in EEGs; Rolandic spikes; the hippocampus in epilepsy

In the EEG of adults patients with temporal lobe epilepsy, spikes indicating abnormal electrical activity are observed in the anterior temporal area, while spikes in the EEG of epileptic children are often seen in the mid-temporal region. (Fig. 1) These spikes in the mid-temporal region are called "mid-temporal spikes" by American authors (Gibbs and Gibbs 1959/60; Lombroso 1967), but some European authors (Beaussart 1972; Blom et al. 1972; Loiseau and Beaussart 1973) call these spikes "centro-temporal spikes" or "Rolandiing spikes," because they appear not only in the mid-temporal area but also in the central region. In this paper, however, these spikes will be called mid-temporal spikes, because the author thinks these spikes probably originate in the deep structure of the temporal lobe, i.e., the hippocampus (Ichijoh 1985, 1986).

Mid-temporal spikes can be seen not only in children with epilepsy, but also

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Fig. 1. An example of mid-temporal spikes. This is of a case of a 6-year-old boy with epilepsy. The EEG on the left is derived with reference to the ears (A1 and A2). Spikes appear in the left mid-temporal (T3) and central (C3) regions (dots). Negativity is upward. The EEG on the right was derived by means of a longitudinal bipolar derivation. Negative spikes are expressed in out-of-phases (arrows).

in cases of febrile convulsion, mental retardation and head injury. These spikes appear after 2 to 3 years of age and most frequently occur in children 8 to 10 years of age. Even if these spikes appear in children with epilepsy, the children usually have a good prognosis, and both epileptic seizures and mid-temporal spikes in the EEG mostly disappear after the age of 12 or 13. For this reason, this type of epilepsy in children is often called “benign childhood epilepsy” (Beaussart 1972; Blom et al. 1972; Loiseau and Beaussart 1973; Dreifuss et al. 1985). This is quite different from temporal lobe epilepsy in adult patients, for which the prognosis is not necessarily good.

Clinical seizures occurring in benign childhood epilepsy with mid-temporal spikes are variable. Lombroso (1967) summarized this type of seizure as follows. “First, there is almost always some somatosensory involvement, most often of the tongue, but occasionally of inner cheeks, lips or gums, or even of a single tooth, while typical visceral aurae are rare. .... More rarely a vertiginous component may be present. Second, speech arrest, not due to dysphasia but to motor interference, or anarthria. Third, preservation of consciousness, in most cases. Fourth, excessive pooling of saliva. Fifth, commonly, tonic or tonic-clonic spread to face or arm; very rarely, the occurrence of a typical jacksonian march.”
He called this benign childhood epilepsy with mid-temporal spikes "sylvian" seizure, because he considered the sylvian fissure to be the origin of these seizures.

Concerning mid-temporal spikes, the author has several questions. Lombroso (1967) thought that the mid-temporal spikes originated in the sylvian fissure, especially the lower Rolandic cortex, but there is no evidence of epileptogenic lesions and no particular anatomical structure in this cortex. Moreover, mid-temporal spikes appear not only in the mid-temporal region but also in the central (Rolandic) region. However, anatomically there are no associative fibers or neuronal connections between the temporal area and the central (Rolandic) area. Lombroso (1967) used the term "sylvian seizure," but the type of seizures are not constant. Loiseau and Beaussart (1973) stated that the signs noted during these seizures are variable. Blom et al. (1972) described the symptoms as often appearing bilaterally in the face or limbs. These variable and bilateral symptoms cannot be explained if it is supposed that a particular localization has taken place as Lombroso (1976) has stated.

In the EEG, mid-temporal spikes often appear bilaterally with a higher amplitude on one side and with a lower amplitude on the other side. Penfield and Jasper (1954) called the region with spikes of a higher amplitude the primary focus and the other region with spikes of a lower amplitude the "mirror focus." They thought that disturbances in one hemisphere were transmitted over the corpus callosum to the opposite side and produced "mirror focus." However, as far as the anatomy of the corpus callosum is concerned, there are no commissural fibers connecting the two side temporal lobes. It is difficult, therefore, to explain "mirror focus" using Penfield and Jasper's theory of the corpus callosum, for as Geschwind (1965) stated, "mirror foci" should be rare when commissural connections are lacking.

Questions concerning the origin and the neuronal mechanism of mid-temporal spikes are summarized as follows. First, there is no evidence of epileptogenic lesions or special structures in the area where mid-temporal spikes are present. Secondly, mid-temporal spikes appear in the central and temporal regions and are sometimes called centro-temporal spikes, but anatomically there is no associative connections between the central and temporal areas. Thirdly, mid-temporal spikes often appear bilaterally and can be called "mirror focus." Clinical signs are also variable, and bilateral symptoms are often observed. It is difficult to explain these EEG findings and clinical features if a particular localized cortex origin is assumed. Therefore, an alternative theory must be postulated to explain the origin and of the neuronal mechanism of mid-temporal spikes.

The author would hypothesize that the hippocampus is the origin of mid-temporal spikes and that electrical activity spreads to the scalp by volume conduction. In this study it will be shown that the various scalp distributions of mid-temporal spikes can be explained if it is hypothesized that electrical dipoles are generated in the hippocampus.
SUBJECTS AND METHODS

The EEGs were recorded with subjects in a supine position using disc electrodes which were fixed with EEG paste. Electrode positions were according to the 10-20 system, and EEG montages were ear-lobe-referential, bipolar (longitudinal and transverse), and average referential derivation. The EEGs were taken during waking and sleeping states and, if possible, during hyperventilation and photic stimulation.

The EEGs which showed mid-temporal spikes were selected from daily clinical EEG examinations, which were done from 1969 to 1986. The number of cases and EEGs were 50 (30 boys and 20 girls) and 128, respectively. The subjects were from 2 to 15 years of age. Clinical diagnoses or conditions were as follows: epilepsy, 18; mental retardation, 10; febrile convulsion, 7; headaches, 5; head trauma, 4; etc.

Classification of mid-temporal spikes

Mid-temporal spikes can be classified into 4 types based on the scalp distribution of spikes as shown in Fig. 2. Type 1 is characterized by mid-temporal spikes which appear unilaterally on one side of the scalp. In type 2 mid-temporal spikes appear bilaterally and synchronously on both sides of the scalp. This type of EEG has been said to show "mirror focus." Type 3 is characterized by mid-temporal spikes which appear bilaterally and synchronously, but the polarities of the spikes are in opposite directions on the two sides, for example, negative on the left and positive on the right.

![Fig. 2. Classification of mid-temporal spikes. Upper channels with odd numbers are for EEGs of the left scalp and lower channels with even numbers are for EEGs of the right scalp. Mid-temporal spikes can be classified into 4 types. Type 1: unilateral spikes (●). Type 2: bilateral and synchronous spikes (● and •). Type 3: bilateral and synchronous, but the polarities of these are in opposite directions on the two sides, in this figure, negative on the left and positive on the right (● and ×). Type 4: bilateral and asynchronous spikes (● and ○).]
left and positive on the right as shown in Fig. 2. In type 4 mid-temporal spikes appear bilaterally, but are asynchronous and independent on both sides. These cases of type 4 can also be said to have “mirror focus.”

The number of cases in each type were as follow:

Type 1: unilateral mid-temporal spikes, 25 cases (left side, 14; right side, 11).

Type 2: bilateral synchronous mid-temporal spikes showing “mirror focus,” 8 cases.

Type 3: bilateral synchronous mid-temporal spikes with the two sides having opposite polarities, 2 cases.

Type 4: bilateral asynchronous mid-temporal spikes, 15 cases.

In this classification, cases with more than one type of spike were classified as one of the lower types.

The author’s interpretation of the different type of mid-temporal spikes

The author would explain these different types of mid-temporal spikes by hypothesizing that the hippocampus is their origin. In the transverse section of the hippocampus, pyramidal cells are arranged in the form of the letter “C”, as shown in Fig. 3. Therefore, if electrical activity of the spikes is generated in the pyramidal cell layer, the axis or vector of electrical dipoles will have different angles depending on its location. As Fig. 4 shows, if the axis of electrical dipoles is oblique, the spike potential will spread unilaterally, but an opposite pole of the
Fig. 4. Hypothetical electrical field of mid-temporal spikes generated in the hippocampus. If the axis (vector) of electrical dipoles is oblique, the electrical potential will spread to the scalp unilaterally, but an opposite pole of the potentials will not appear (Type 1). If the axis of electrical dipoles is vertical, the potential will spread bilaterally (Type 2). If the axis is horizontal, the potential will spread bilaterally with opposite polarities on the two sides (Type 3). With regard to bilateral asynchronous spikes (Type 4), the two hippocampi may be involved in generation of the spikes.

DISCUSSION

The author would hypothesize that the hippocampus is the origin of mid-temporal spikes. The hippocampus is easily affected by many different conditions and can produce high amplitude electrical activity. In animal experiments, a large millivolt electrical potential has been observed in the hippocampus (Green 1981). Green and Shimamoto (1953) stated that the current changes in the hippocampus can be large enough to produce voltage changes at some distance within the volume conducting system of the brain. Hughes and Schlagenhauff
(1961) stated that hippocampal activity would probably appear on the mid-temporal electrode.

Since the author's hypothesis (Ichijoh 1985, 1986) was presented, it has been discussed by many people. One of the most common questions is whether the electrical activity of the hippocampus can be recorded by using scalp electrodes. Traditionally, it has been said that it is difficult to use scalp electrodes to record the electrical activity of deep structures of the brain such as the hippocampus and that it is only possible to record the activity of deep structures using special depth electrodes.

In answering this question, it should be remembered that the method of recording electrical activity in deep structures of the brain has employed a bipolar derivation. Fig. 5 shows electrocardiogram recordings; the first 8 channel recordings were obtained by using bipolar derivations. Apparently no activity was recorded on channels 1-3 and 3-5 of the left arm, and on channels 2-4, 4-6, and

![Figure 5](image)

Fig. 5. This figure shows electrocardiogram recordings. The first 8 channel recordings were obtained by using bipolar derivations. Apparently, no activity was recorded on channels 1-3 and 3-5 of the left arm, and on channels 2-4, 4-6, and 6-8 of the right arm. However, when an electrocardiogram was derived from the electrodes on the left arm and the right arm, electrocardiogram activity could be recorded. In the case of EEG, it should be remembered that for recording electrical activity in deep structures of the brain by means of depth electrodes, a bipolar derivation is also used. Considering the electrocardiogram recordings shown in this figure, it is theoretically possible to use scalp electrodes to record electrical activity in the deep structures of the brain which may not have been detected by depth electrodes, depending on the direction of EEG derivation and the distance between the scalp electrodes.
6–8 of the right arm. However, when an electrocardiogram was derived from the electrodes on the left arm and the right arm on channels 1–2 and 3–4, electrocardiogram activity was seen. It has been believed that electrical activity originating in the deep structures of the brain cannot be recorded by the scalp electrodes, but as seen in Fig. 5, it is theoretically possible to record deep electrical activity using scalp electrodes, if activity in the deep structures is great enough, depending on the direction of EEG derivation and the distance between electrodes.

The second question concerns “mirror focus.” In Fig. 6, spikes appear in both the left and right mid-temporal areas, and spikes in the left mid-temporal region have higher amplitudes than those in the right mid-temporal area. Penfield and Jasper (1954) called the region with higher amplitude spikes a primary focus and the region with lower amplitude spikes “mirror focus.” They assumed that spikes of the primary focus were transmitted over the corpus callosum to the opposite hemisphere and thus developed the concept of “mirror focus.” They observed that the spikes in the primary focus preceded the spikes in the “mirror focus” by 5 to 10 or even 15 msec, and they thought that this time delay would account for the transmission over the corpus callosum. Thus, a valid question is how the author’s volume conduction theory can explain this time delay between the spikes on the two sides.

The author, however, has obtained data for another type of case. In Fig. 7, the spikes with a higher amplitude are preceded by the spikes with a lower amplitude. This time relation is contrary to the one in Fig. 6. How can this paradoxical time relation be explained? Usually, higher amplitude activity

![Figure 6](image_url)

Fig. 6. The time relation of bilateral spikes. The EEG was recorded with a higher paper speed. The odd numbers of electrode positions stand for the left side of the scalp, and the even numbers stand for the right side of the scalp. There is a time difference between higher amplitude spikes on the left and lower amplitude spikes on the right, and higher amplitude spikes precede lower amplitude spikes (T3-A1 vs. T4-A2). It has been thought that this time delay accounts for the transmission of the spikes over the corpus callosum.
Fig. 7. Another kind of time relation of bilateral spikes. The time relation in his figure is contrary to the one in Fig. 6. Higher amplitude spikes on the left are preceded by lower amplitude spikes on the right (T3-A1 vs. T4-A2: T3-Fz vs. T4-Fz). This time relation cannot be explained by transmission of spikes over the corpus callosum.

The third question is that if mid-temporal spikes originate in the hippocampus, children with the spikes should often have "psychomotor" seizures, i.e., complex partial seizures as seen in adult patients with temporal lobe epilepsy. Such children, however, only occasionally show automatism in spite of the frequent occurrence of spikes in the mid-temporal region of the EEG. The author's hypothesis that mid-temporal spikes originate in the hippocampus does not mean that the origin of the epileptic process itself exists in the hippocampus. Mid-temporal spikes may be non-specific phenomenon secondarily resulting from various etiologies and possibly due to hereditary predisposition, because these spikes are observed not only in epileptic children but also in non-epileptic children, and because the spikes often appear bilaterally and asynchronously in one-third of the cases in this study, suggesting the involvement of the two hippocampi. Therefore, if children do not have "psychomotor" seizures, it can be considered to be inconsequential. Children with mid-temporal spikes often show bilateral spike-and-slow-wave complex bursts. As seen in Fig. 8, this bilateral spike-and-slow-wave complex activity should be regarded as more indicative of a
Fig. 8. Mid-temporal spikes and bilateral spike-and-slow-wave complex bursts.

The EEG shows a bilateral spike-and-slow-wave complex burst and it is immediately followed by localized spikes in the right mid-and posterior temporal regions (T4 and T6). It is likely that a bilateral complex burst may be more indicative of a primary process and that mid-temporal spikes may be more indicative of a secondary process.

primary process and mid-temporal spikes as more indicative of a secondary process.

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References


