Mapping Epileptic Foci by the Dipole Tracing Method in a Brain Tumor Patient with Olfactory Seizures: Comparison with Intraoperative Electrocorticograms

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Key Words Brain Tumor Dipole Tracing Method Electrocorticography Epileptic Focus Olfactory Seizure ~~ ~~

INTRODUCTION

The Dipole Tracing Method (DTM) was developed and named by Homma et al.' DTM is an analysis to calculate the location of the EEG source from recorded EEG signals and approximates the source to one or more dipoles. DTM can determine the location of the dipoles by iterative calculations using algorithms minimizing the squared difference between the potentials actually recorded from the scalp and those calculated from the dipoles.

There are many brain mapping methods based on the equivalent current dipole (ECD) which estimate the location of the electrical source.² Several of these are based on calculations derived from brain potentials and, as they postulate a standardized model of the head, they are inaccurate and there have been no reports comparing the calculated positions with the epileptic foci.

In recent years four brain mapping methods, including our methods, have been developed using the true shape of the head.^{1,35} All of them use a boundary element algorithm composed of three layers and accuracy has become much higher. However, there have been few reports that compare the calculated positions with the actual locations of the epileptic foci. In this study we estimated the locations of epileptic foci using $DTM^{1,6}$ in a patient with a brain tumor and compared the results with electrocorticograms (ECoGs) recorded during surgical resection in order to show the high accuracy of DTM.

CASE REPORT

The patient was a 24-year-old male, the product of a normal delivery. His family history for epilepsy was unremarkable. In 1990 (at 18 years of age) the patient began to experience "bad odors" lasting 20-30 seconds 2-3 times a day. At 20 years of age he began to experience attacks of unconsciousness lasting about 1 minute, 1-2 times a month, and was examined at Hospital T. The patient began to take antiepileptic drugs, but there was no change in the

frequency of the seizures. After about 2 months, he decided to stop taking them. Although the seizures persisted, he did not seek medical advice until **an** attack of unconsciousness occurred at work. He was then examined in our department in April 1995 on the advice of his superior. An EEG examination revealed frequent spikes, predominantly at FB, T4, and T6. A MRI examination of the head revealed a homoge neous high intensity mass on the T2-weighted image in the right temporal lobe-hippocampus-amygdala region. The patient was immediately referred to the Neurosurgery department of our hospital. Anterior temporal lobectomy was performed on July 20, 1995. The tumor was found in the right uncus extending to the right amygdala. The size of the tumor was about 3 x 3 x 2 cm. A 5-cm anterior temporal lobe and a 2.5 -cm anterior hippocampus were resected. Histologically the tumor was a benign ganglioglioma. There have been no seizures since the operation, and no spikes have been detected on EEG examinations to date.

METHODS

An EEG was recorded from 21 electrodes arranged according to the International 10/20 System. The reference electrode was placed on the left ear lobe. All of the EEGs were recorded using a data recorder (XR-9000; TEAC) for later analysis. Sampling rate was 1000Hz. Onedipole analysis was performed on the spike peaks using an EEG analyzer (CDT-1000; Chuo Electronics Co. Ltd., Tokyo, Japan). Dipole estimations of the same spikes were performed at 5 different consecutive time points with an interval of 1 msec. Creating a three-layer **(SSB)** model,' horizontal slices produced by X-ray CT at 5-mm intervals were read by scanner, 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 was the brain layer. The ratio of the electric con-

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Figure 1.

The **ECDs** *on* **a MR image,** *located* **in the hippocampus.**

Figure 2.

The **ECDs** *on* **a MR image,** *located* in **the nght superior** temporal **gyrus.**

Figure 3. An ECoG of the right hippocampus.

Figure 4.

temporal gyrus. **A recording** with **the strip electrode** placed *on* the nght **superior**

ductivity of the layers was calculated as 1:1/80:1.⁷ The equivalent cunent dipole (ECD) was computed as vectors on the coordinates of a 3-dimensional model of the head, and the calculated position was marked *on* a MR image. EEG recording time was about **1** hour, and **14** representative spikes chosen by inspection from the spikes that appeared were used as the subject of the analysis. As a result of **the** analysis, only ECDs in which dipdarity was 98% or more were adopted to avoid aliasing.'

The ECoG recorded spikes in two places, one in the nght temporal **bbe and** the other in the nght hippocampus. In the nght temporal lobe, **the** ECoG *oneachcerebralgyfus* was recorded with **bipolar** leads using a **strip** *electrode con*sisting of **10** *electrodes* in **2** rows. Later the ECoGs *on* **the** right hippocampus were recorded with bipolar leads using a strip electrode consisting of **4** electrodes in a single row. were made comparing **them** with the intraoperative video recording showing **the** *elecbodes on* **the** brain. The schematic diagrams of the position of the *electrodes*

RESULTS

Two of the **14** spikes analyzed were exduded from **the** results because the dipolarity was less than 98%. Twentyfive ECDs were mapped to the right hippocampus from 5 of **the 12** spikes adopted, and **35** ECDs to **the** right superior temporal **gyfus** using the remaining 7. Thus, they were mapped to two places, the right hippocampus or **the** right superior **temporal** gyrus, independently by DTM.

Fgure 1 shows the posrtions of the ECDs *on* the right hippocampus *on* a MR image. The EEG *on* the lefl of the image **shows** the typical spike analyzed. The ECDs are located in the right hippocampus adjacent to the posterior ECDs *on* a MR image. The ECDs are located in the right superior **temporal** *gym.* portion of the lesion. Figure 2 shows the positions of these

Fgure **3** *shows* an ECoG of the right hippocampus. A

Figure 5.

schematic diagram of **the** position of **the** electrodes *on* **the** hippocampus is at **the** lower left of the figure. The electrode numbers correspond to the number of the leads on **the ECoG** at **the upper** nght. We marked the approximate positions of **ECDs** with an asterisk. On the **ECoG**, spikes appeared in leads 1-2 and **2-3.** and phase reversal is *seen,* suggesting that the epileptic locus is located in **the** vicinity of electrode 2. This almost matches **the** positions 01 **the ECDs mapped** in **the** hippocampus by DTM. Fgure 4 *shows* a recording with **the** strip electrode placed *on* the right superior temporal gyrus, and Figure 5 shows the **ECoG** recorded in **the** vicinity 01 the right temporal lobe. A schematic diagram of the electrodes placed *on* **the** cerebral cortex is shown at **the** left of **the** figure. **ECoGs** were recorded at different **times** from **the** frontal lobe, superior temporal **gyrus,** middle temporal **gynrs,** and inferior temporal **gyrus, and** arranged **as** shown in **the** figure. Spikes were frequently recorded in leads **I-J.** Positive *spikes* are *seen* in leads **0-P. The** time that they were recorded is **dif**ferent but their polarity is reversed, suggesting that the epileptic **focus** is in the vicinity 01 electrodes J **and** 0. This site bears a *close* correlation with the **ECDs** mapped in the right superior temporal gyms by DTM.

DISCUSSION

In **the** present **study** we used DTM to map **the** epileptic loci of a patient with a brain lesion. Two independent locations were mapped **as** a result, *one* in the right hippocampus and the other in the right superior temporal **gyms.** Spikes were recorded in the right hippocampus **and the** right superior temporal **gyrus** *on* **the ECoGs** of **this** patient. These places matched the positions mapped by DTM, proving that mapping by DTM is highly accurate.

Our patient had two foci, *one* near **the tumor** and **the** other **detached** from it. He had no seizures caused by **the** epileptic locus in the right superior temporal **gym;** therelore, **this** focus mlght be **the** secondary locus incubated by **the tumor.** AIthough the reason why **the** focus appeared was undear, **the ECoG** dearly *showed* that **the** epileptic locus lay in **the** nght **superior** temporal **gyrus.** In **the** past, **the** epileptic foci in patients with seizures caused by brain lesions were claimed to lie in the vicinity of the lesion. However, as a result of advances in brain mapping, epileptic foci have been found **not** only near brain lesions, but, in quite a **few** exceptional *cases some* distance away from them, or two foci with one close, but the other some distance away from them.⁶¹⁰ We thought our patient was **also an** exceptional *case.*

Our subject was a brain tumor patient with seizures, not **an** epileptic patient without a brain lesion. DTM postulates a uniform parenchyma 01 the brain, **so** the large lesion that is different from the normal brain parenchyma in the electric conductivity **makes the** mapped points inaccurate. The results of **the** present *study show* that DTM is highly accurate. panially because **the** brain **lesion** was **not** **so** large and the electrical conductivity level of the lesion was close *to* that of the brain parenchyma.

Flink et al¹¹ have reported that DTM is highly accurate in epileptic patients, although their sample was small and they have not examined the details. Roth et al¹² have illustrated the difference between the calculated position and the epileptic foci using their method. They found a considerably large spread in the ECoGs. No mapping methods derived from brain potentials have shown the difference between the calculated position and the epileptic foci on a diagram. There have been no reports that the difference between them was calculated, because there is some spread in both the calculated positions and the epileptic foci and it is difficult *to* calculate this spread. In this study our recording time of the ECoG was too short to examine the brain extensively. We could, however, find the epileptic foci clearly, **as** there was, fortunately, only a small spread in the ECoGs *of* our patient. The results of the present study show on a chart that the calculated positions and the epileptic foci were very close. Therefore, we conclude that DTM is highly accurate in patients with brain lesions associated with epileptic seizures.

DTM is an analysis *to* calculate the location of the EEG source from recorded EEG signals. Using DTM we can find the location of the epileptic foci and get material

to judge surgical indication of epileptic patients. DTM **is** a noninvasive method *to* examine all patients whose EEG can be recorded. In addition, DTM only needs simple equipment including a computer and some input units. In this study we used a three-layer SSB model. We are **now** developing a realistic four-layer (SSLB) model in consideration *of* liquor layer space: DTM will be developed and become more accurate.

SUMMARY

We estimated the position of the epileptic foci in a case of brain tumor with olfactory seizures using the Dipole Tracing Method (DTM) and compared the results with electrocorticograms (ECoGs) recorded during surgical resection. The case was a 24-year-old male. Electroencephalograms (EEG) showed frequent focal spikes in the right temporal area. Magnetic resonance imaging revealed a tumor in the right hippocampus region. We analyzed the spikes using DTM with a CDT-1000 EEG analyzer. The locations of two independent foci were analyzed; one was thought *to* be in the right hippocampus and the other in the right superior temporal gyrus. When the ECoG was taken, the results were in very close correlation with those of DTM, demonstrating the accuracy of DTM in the estimation of the location of epileptic foci in epileptic seizures with brain lesions.

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