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

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INTRODUCTION

The Dipole Tracing Method (DTM) was developed and named by Homma et al.¹ 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.^{1,3-5} 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 F8, T4, and T6. A MRI examination of the head revealed a homogeneous 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,1 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 right hippocampus.



Figure 2.

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



Figure 3. An ECoG of the right hippocampus.



Figure 4.

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

ductivity of the layers was calculated as 1:1/80:1.⁷ The equivalent current 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 dipolarity was 98% or more were adopted to avoid aliasing.¹

The ECoG recorded spikes in two places, one in the right temporal lobe and the other in the right hippocampus. In the right temporal lobe, the ECoG on each cerebral gyrus was recorded with bipolar leads using a strip electrode consisting 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. The schematic diagrams of the position of the electrodes were made comparing them with the intraoperative video recording showing the electrodes on the brain.

RESULTS

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

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

Figure 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 right. 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 focus is located in the vicinity of electrode 2. This almost matches the positions of the ECDs mapped in the hippocampus by DTM. Figure 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 of 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 gyrus, 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 O-P. The time that they were recorded is different but their polarity is reversed, suggesting that the epileptic focus is in the vicinity of electrodes J and O. This site bears a close correlation with the ECDs mapped in the right superior temporal gyrus by DTM.

DISCUSSION

In the present study we used DTM to map the epileptic foci 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 gyrus. 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 focus in the right superior temporal gyrus; therefore, this focus might be the secondary focus incubated by the tumor. Although the reason why the focus appeared was unclear, the ECoG clearly showed that the epileptic focus lay in the right 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 of 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, partially 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 al" 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.

REFERENCES

- Homma S, Musha T, Nakajima Y, et al. Location of electric current sources in the human brain estimated by the dipole tracing method of the scalp-skull-brain (SSB) head model. Electroencephalogr Clin Neurophysiol 1994; 91: 374-382.
- Nakasato N, Levesque MF, Barth DS, Baumgartner C, Rogers RL, Sutherling WW. Comparisons of MEG, EEG, and ECoG source localization in neocortical partial epilepsy in humans. Electroencephalogr Clin Neurophysiol 1994; 91: 171-178.
- Roth BJ, Balish M, Gorbach A, Sato S. How well does a three-sphere model predict positions of dipoles in a realistically shaped head? Electroencephalogr Clin Neurophysiol 1993; 87: 175-184.
- Cuffin BN. A method for localizing EEG sources in realistic head models. IEEE Trans Biomed Eng 1995; 42: 68-71.
- Yvert B, Bertrand O, Echallier JF, Pernier J. Improved dipole localization using local mesh refinement of realistic head geometries: an EEG stimulation study. Electroencephalogr Clin Neurophysiol 1996; 99: 79-89.
- Shibata N, Hattori S, Kifune A, Kubota F, Machiyama Y, Takahashi A. Estimation of epileptic foci by dipole tracing method in epileptic seizures with structural lesions of the brain. Epilepsia 1997; 38 (suppl 3): 210.

- Homma S, Musha T, Nakajima Y, et al. Conductivity ratios of the scalp-skull-brain head model in estimating eqivalent dipole sources in human brain. Neurosci Research 1995; 22: 51-55.
- Awad IA, Rosenfeld J, Ahl J, Hahn JF, Lüders H. Intractable epilepsy and structural lesions of the brain: mapping, resection strategies, and seizure outcome. Epilepsia 1991; 32: 179-186.
- Boon PA, Williamson PD, Fried I, et al. Intracranial, intraaxial, space-occupying lesions in patients with intractable partial seizures: an anatomoclinical, neuropsychological, and surgical correlation. Epilepsia 1991; 32: 467-476.
- Kamada K, Isu T, Takahashi T, Tanaka T. Remote epileptogenic focus detected by electrocorticogram in a case of cavemous angioma. Acta Neurochir (Wien) 1994; 127: 236-239.
- Flink R, Sigfrid B, Hagbarth KE. The electric dipole method in the preoperative evaluation of epilepsy surgery patients. Electroencephalogr Clin Neurophysiol 1995; 97: S79-S80.
- Roth BJ, Ko D, von Albertini-Carletti IR, Scaffidi D, Sato S. Dipole localization in patients with epilepsy using the realistically shaped head model. Electroencephalogr Clin Neurophysiol 1997; 102: 159-166.