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Identification and removal of an epileptogenic lesion using Ictal-EEG, functional-neuronavigation and electrocorticography

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Summary Purpose: Cases with intractable epilepsy may present with multiple lesions in their brains. Ictal-EEG carries a great value in identification of the primary epileptogenic source. On the other hand, removal of low-grade tumors located around the eloquent cortex may be risky with conventional techniques. Functional-neuronavigation (f-NN) is the integration of functional magnetic resonance imaging and stereotactic technologies; and provides interactive data regarding localization of the motor cortex. This report presents a case with dysembryoplastic neuroepithelial tumor (DNET), which was removed using f-NN and electrocorticography (ECoG) techniques. **Methods:** A 19-year-old patient with intractable complex partial and secondary generalized seizures is presented. MRI revealed a low-grade tumor located in right parietal region just behind the motor cortex, and a contralateral temporal arachnoid cyst. Ictal-EEG demonstrated the right parietal origin of the seizures. The patient underwent a right parietal craniotomy and tumor excision using f-NN and ECoG techniques intraoperatively. ECoG findings correlated with epileptogenicity of the parietal lesion. **Results:** Postoperative course was uneventful. No postoperative deficit was observed. The patient was seizure free in eight months follow-up. Pathological examination reported the lesion as DNET. **Conclusions:** Ictal-EEG has a very important role in identification of the epileptogenic focus in cases with multiple brain lesions. Preservation of the functional cortex is the most prominent aim during lesional surgery of epilepsy. Intraoperative mapping using f-NN and ECoG supports the orientation of the neurosurgeon to the functional and epileptogenic cortical areas; and thus, increase the safety and efficacy of surgical procedures.

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INTRODUCTION

Cases with intractable epilepsy may present with multiple lesions in their brain. Ictal-electroencephalography (I-EEG) carries a great value in identification of primary epileptogenic source. On the other hand, removal of low-grade tumors located around the eloquent cortex may be risky with conventional techniques. Functional-neuronavigation (f-NN) is the integration of functional magnetic resonance imaging and stereotactic technologies which provides interactive data regarding localization of the motor cortex. This case report presents a case with dysembryoplastic neuroepithelial tumor (DNET), which was examined with I-EEG preoperatively and removed using f-NN with intraoperative electrocorticography (ECoG).

CLINICAL PRESENTATION

History and examination

A 19-year-old male patient suffered from intractable complex partial and secondary generalized seizures for nine years. A typical seizure would start with an aura, then contraction of left arm and followed by generalization. Urinary incontinence and tongue biting were occasionally observed. Neurological examination revealed no abnormality. A head trauma was described in the medical history. Carbamazepine was prescribed to the patient with a dose of 1200 mg daily. Cranial magnetic resonance imaging (MRI) revealed a T2 hyperintense lesion located in the right parietal lobe lying on the postcentral gyrus approximately measuring 1.5 cm in diameter. The lesion had blurry margins without any mass effect or peripheral edema. It was hardly detected on T1 weighted images with a iso-hypointense signal pattern but showed mild homogenous enhancement on postcontrast series (Fig. 1(a)). A temporal arachnoid cyst in the left middle temporal fossa and accompanying temporal lobe atrophy were also detected on the contralateral side of the brain (Fig. 1(b)).

Ictal-EEG

The patient was monitored at Gazi University Telemetry Center with long term EEG. He felt only tightness of his left arm in the first monitoring session and no I-EEG abnormality was seen. These seizures were classified as simple partial seizures. The patient had one seizure in the second monitoring session. He initially felt tightness and contraction of his left arm and leg, then turned his head to the left and followed by generalization. Seizure activity began in the right parietal region (P4 electrode position), spreaded to the right initially and then to both hemispheres after 5–10 s. The seizure origin and the lesion were located very close to the eloquent cortex. Although cranial MRI revealed a dual pathology, the origin of the seizure was not in the left temporal region.

f-MRI and f-NN

Preoperative functional magnetic resonance imaging (fMRI) using blood oxygen level dependent (BOLD) technique was performed on a 1.5 T MR unit (Signa Horizon, Echo-Speed, GE Medical

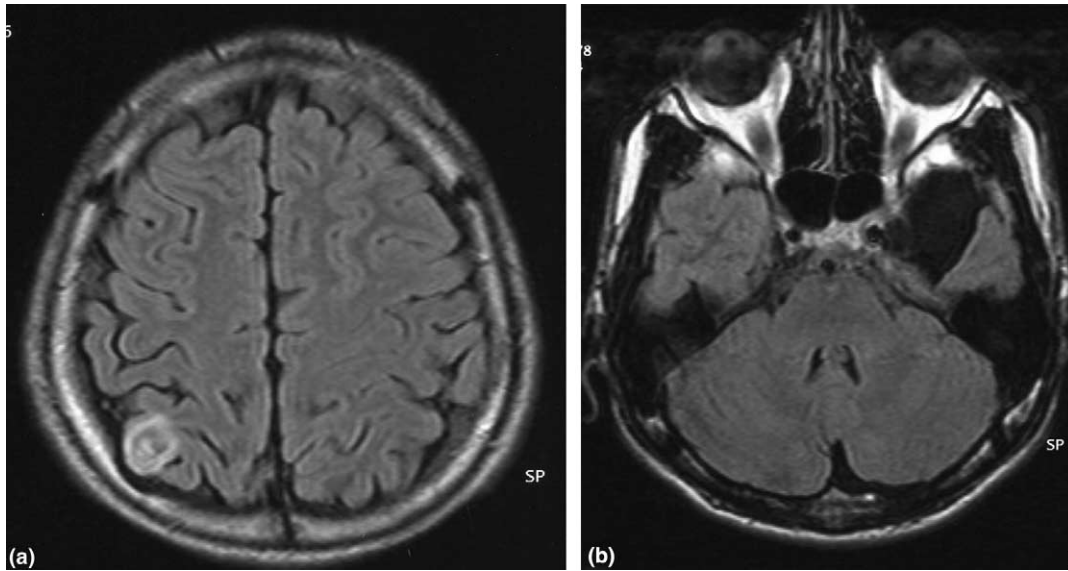


Fig. 1 (a) Preoperative magnetic resonance imaging studies. T1-weighted axial images demonstrating iso-hypointense lesion at the right parietal lobe. (b) T2-weighted axial images revealing a temporal arachnoid cyst in the left middle temporal fossa.

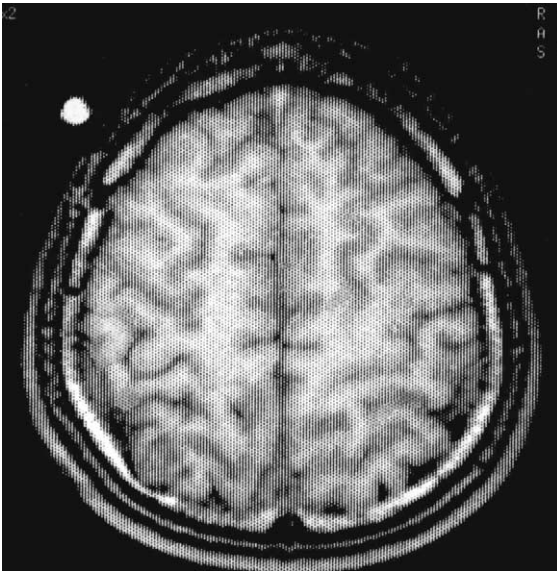


Fig. 2 The primary motor cortex was shown in coloured preoperative f-MRI.

Systems, Milwaukee, WI, USA) equipped with echoplanar imaging hardware. Ten contiguous axial slices of 5 mm thickness were collected during the EPI-GRE sequence (TE: 60 ms, TR: 3000 ms, FA: 90°, Matrix: 64 × 64, NEX: 1, FOV: 24 cm). Total scan time was 2.5 min consisting of five equal parts of 30 s, starting and ending with a rest period. The motor task was finger clenching. Image analysis was performed with “GE Functool” software system and activated maps demonstrated the primary motor cortex lying very closely in the anterior aspect of the tumor (Fig. 2). These maps were loaded on a stereotactic neuronavigation system software (Vector-Vision 2, Brain Lab, München) with landmark correlation.

Surgery

Both the primary motor cortex and the tumour area coded with different colors were projected on to the patient’s brain during surgery. Complete tumor resection was performed after comparing with the results of intraoperative electrocorticography (Figs. 3(a) and (b)) and f-NN (Figs. 4(a) and (b)).

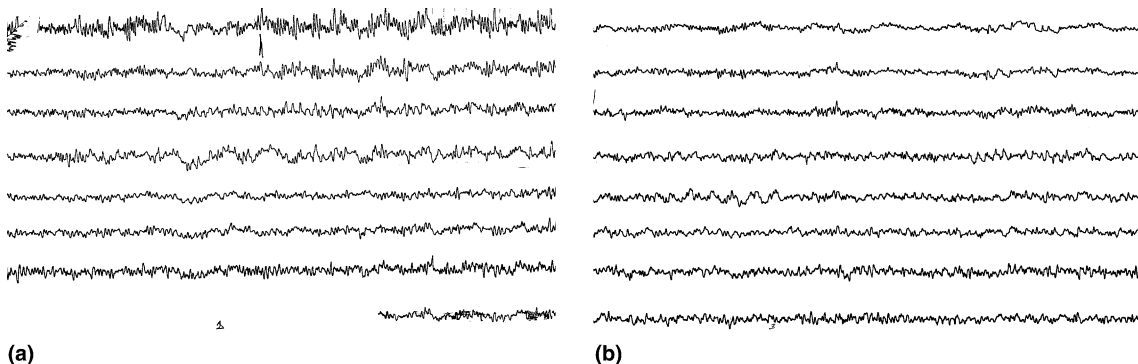


Fig. 3 (a) EcoG performed over the lesion. Delta slowing is seen on electrodes 4 and 5. Electrodes 1 and 2 was 3–4 cm superior the lesion and fast activity is seen on these electrodes which could be compatible with motor cortex. Sensitivity (S): 15 mV, high frequency filter (HFF): 70 Hz, low frequency filter (LFF): 1 Hz. (b) EcoG was done using an eight contact strip electrode. Reference electrode was on ipsilateral ear and strip was placed on just anterior the lesion. Delta and theta slowing is seen on electrodes 4 and 5. (S: 15 mV, HFF: 70 Hz, LFF: 1 Hz).

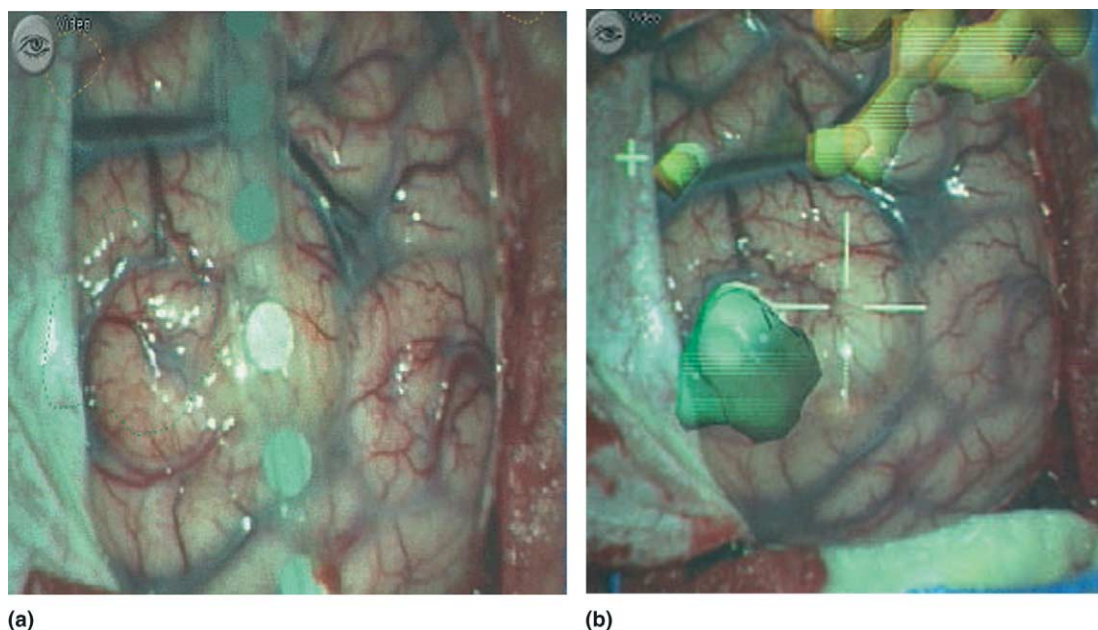


Fig. 4 (a) Intraoperative photograph showing the strip electrode placed over the lesion. (b) Intraoperative microscope view with f-NN: The lesion was seen in green coloured and the primary motor cortex located anterior of the lesion was seen in yellow coloured.

Postoperative course

Postoperative course was uneventful. No postoperative deficit was observed. The patient was seizure free in eight months follow-up. Pathological examination reported as dysembryoplastic neuroepithelial tumour (DNET). The patient's neurological examination was found to be normal at the last postoperative follow-up eight months after the operation.

DISCUSSION

The main goal of surgery with intracranial lesions adjacent to or within the sensori-motor cortex is to achieve complete resection of the lesion while preserving normal brain tissue and function. Removal of space occupying lesions in the sensori-motor region carries a considerable risk of postoperative paresis. Serving for this purpose presurgical cortical mapping with f-MRI is gaining acceptance in clinical practice.⁷ Accurate localization of the motor cortex is very important in cases when tumours are situated in the peri-Rolandic area in order to reduce the risk of postoperative neurological deficit. Primary motor cortex might be structurally distorted in patients with brain tumors. On the other hand f-MRI may take an important role in demonstrating the exact position of the functional cortex preoperatively since the location of the eloquent cortex may show great variation among population.³ Intraoperative cortical mapping studies showed that f-MRI is highly accurate in determining the probable margin between the eloquent brain region and the portion of the brain to be resected.^{3,5,7,11} Although this is not a new procedure, stereotactic neuronavigation performed with the guidance of f-MRI is a recent technique expected to make the procedures safer for removal of tumours located around the eloquent cortex.^{1,6}

Cranial neuronavigation is used primarily for better anatomical orientation.¹² MRI and computed tomography are often unable to distinguish between tumor and edema or gliosis especially for low grade gliomas. The integration of f-MRI with cranial NN helps solving this problem. The f-MRI can combine detailed anatomical information with precise physiological information to create a structural and functional model of an individual's brain. This in-

formation can be used preoperatively for surgical planning and intra-operatively for guiding surgical resection strategies. The combination of anatomical and physiological information makes f-MRI an ideal tool for intracranial navigation. Invasive cortical mapping techniques are commonly used either before (surgical implantation of subdural EEG strips) or during surgery (direct cortical stimulation or EcoG) to localize specific functional areas and epileptic focus on the cortical surface.⁷ If the proposed surgical target was adequately distant from the functional motor area as determined by f-MRI, invasive mapping is deemed unnecessary. On the other hand if the target is lying immediately adjacent to the functional area as in our case, invasive mapping should be performed.⁷

Video/EEG monitoring is widely accepted as a cornerstone of the comprehensive diagnostic work-up in patients with seizures. The aim of video/EEG monitoring is to evaluate seizures, classify epilepsy and differentiate pseudoseizures. If the patient is a surgical candidate, he/she is monitored to determine the epileptogenic focus.^{2,10,13} Prolonged interictal EEG monitoring increases diagnostic yield when compared with routine EEG. Interictal EEG analysis demonstrated additional focal abnormalities in more than 20%. Ictal-EEG monitoring is necessary for the determination of epileptogenic focus. The behavioral pattern of seizures can also be observed by video/EEG monitoring.² The clinics, interictal, Ictal-EEG and neuroradiological findings must be correlated in the patients for surgery.^{10,13} Our patient had a dual pathology in cranial MRI. MRI revealed a tumor located in the right parietal region just behind the precentral gyrus and a contralateral temporal arachnoid cyst. Ictal-EEG demonstrated the right parietal origin of the seizures and the patient underwent a right parietal craniotomy. Thus, Ictal-EEG has a very important role in identification of the epileptogenic focus in cases with multiple brain lesions. Preservation of the functional cortex is the most prominent aim during lesional surgery of epilepsy.¹ In addition, safe resection boundary can be determined by electrocorticography (EcoG) before and during operation by the way it can be recorded from the cortical surface or the depth layer of the brain. EcoG is especially useful for neocortical epilepsy and identification of epileptic focus.¹³ Intraoperative mapping using f-NN and ECoG

supports the orientation of the neurosurgeon to the functional and epileptogenic cortical areas; and thus, increases the safety and efficiency of surgical procedures.¹

DNET, typically exhibit a multinodular architecture and may be associated with cortical dysplasia. A large majority of DNET that are identified during surgery for epilepsy are located in the temporal lobe and preferentially involve the mesial structures. However, they may develop in any part of the supratentorial cortex and often present in childhood, adolescence or early adult life. They typically present with long-standing drug-resistant partial seizures. Cortical topography of the lesion is an important criterion for differentiating between these tumours and gliomas. MRI demonstrates the cortical location of the lesion better than the CT scan. These tumors are hypointense on T1, and hyperintense on T2-weighted MR images and are not accompanied by neither peritumoral edema nor mass effect. DNETs are benign lesions. Long-term follow-up demonstrated no clinical or radiological evidence of recurrence even in patients with incomplete surgical removal.^{4,8,9} Because of all these features, this type of the tumors must be removed using the functional and neurological localization methods.

When the lesion is located within or adjacent to the motor area, the postoperative neurological outcome is very important. Exact intraoperative anatomical orientation and knowledge of the position of functional cortical regions are necessary to minimize surgical trauma and to avoid postoperative neurological deficits. Additional value of preoperative functional images in NN systems has been demonstrated before. To our knowledge, this is the first report of the integration of f-MRI and EcoG data in cranial neuronavigation. We combined f-MRI and EcoG techniques for localization and visualization of functional cortical areas and their anatomical site in relation to the lesion. This procedure provides safe and effective surgery without postoperative functional deficits.

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