MEDICAL PRACTICE

Magnetoencephalography and its role in evaluation for epilepsy surgery

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Magnetoencephalography is a newly developed technology used for diagnostic and brain mapping imaging during the presurgical evaluation of patients with medically intractable epilepsy. It provides comprehensive localisation of an epileptogenic focus using simultaneous recordings from the entire brain surface. Magnetoencephalography and electroencephalography are considered complementary and confirmatory to one another. We present a patient with magnetic resonance imaging–negative, non-lesional, neocortical epilepsy. Magnetoencephalography was used for re-evaluation of the epileptogenic zone and this enabled subsequent surgical removal of the epileptic focus. The role of magnetoencephalography in epilepsy surgery is discussed in this report.

Case report

A 22-year-old right-handed girl had suffered from refractory epilepsy from the age of 14 years. She had no history of febrile convulsions and she usually had complex partial seizures involving the left limbs, with automatism. She had an altered level of consciousness during her seizures. She was given different combinations of anti-epileptic drugs including topiramate, gabapentin, oxcarbazepine, and sodium valproate, but still had poor seizure control. She had undergone a number of investigations to try to delineate the epileptic focus. Magnetic resonance imaging, including both 1.5 and 3 Tesla, was performed and showed no gross anatomical abnormality responsible for the epilepsy (Fig 1). Interictal scalp electroencephalography (EEG) showed continuous right temporal spikes. An ictal scalp EEG paradoxically showed attenuation of the interictal active spike activity, but did not show any confined and localised signal onset area. An interictal 2-[18F]fluoro-2-deoxy-D-glucose positron emission tomographic (FDG-PET) scan showed right temporal hypometabolism (Fig 2). The findings of the EEG and PET scan showed concordance but the atypical findings of the ictal scalp EEG suggested a neocortical origin. In view of the lateralised right temporal region abnormality seen on the EEG and FDG-PET scan, and the normal magnetic resonance imaging (MRI) findings, it was suggested she be further evaluated with magnetoencephalography (MEG) before considering surgical intervention. Magnetoencephalography revealed a hyperintense signal localised in the right insular region (Fig 3). After passing the Wada test, surgery was offered to the patient. A craniotomy and insertion of subdural grid and strip electrodes were performed. One 4x6 subdural grid was inserted over the fronto-temporal cortex covering the perisylvian region. Three subdural strips were inserted over the temporal base and mesial temporal region, and two subdural strips were inserted over the fronto-orbital and frontal pole regions. The intracranial EEG revealed that there were bursts of paroxysmal fast activity followed

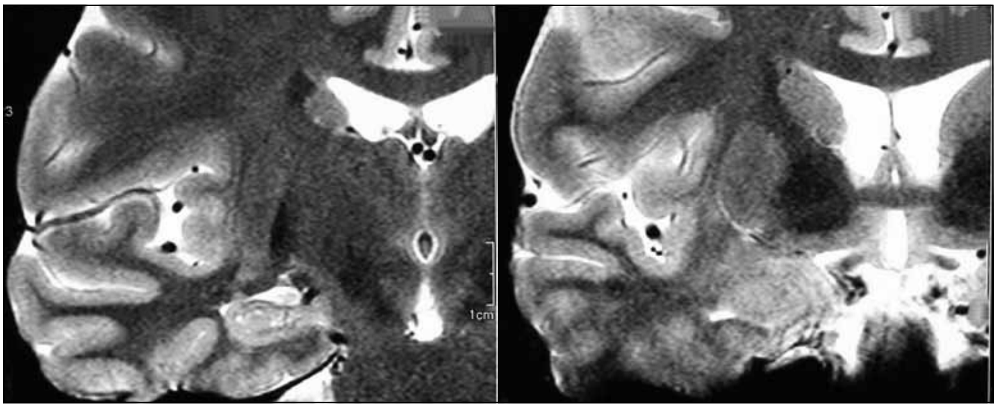

FIG 1. Magnetic resonance imaging scans showing that no gross anatomical abnormality was responsible for the epilepsy

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Epilepsy/surgery; Magnetoencephalography; Preoperative care

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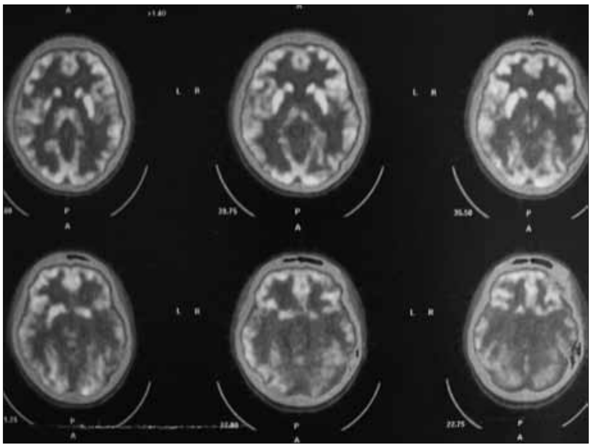

FIG 2. Interictal 2-[18F]fluoro-2-deoxy-D-glucose positron emission tomography scan showing right temporal hypometabolism

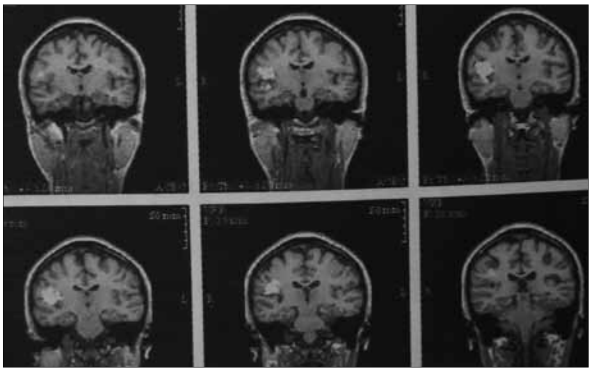

FIG 3. Magnetoencephalographic scans showing a hyperintense signal localised to the right insular region

腦磁圖與癲癇治療手術的關係

腦磁圖屬新開發技術，為難治性癲癇症患者作術前評估時可用作診斷性腦部定位，利用整個腦部表面的即時記錄提供更精確的致癲癇焦點位置。腦磁圖和腦波圖被認為能互相補足和確證。本文報告一名磁共振成像陰性、非損害性腦皮層癲癇症患者，透過腦磁圖重新評估致癲癇區以進行癲癇焦點移除手術。本文也討論腦磁圖在癲癇症治療手術中扮演的角色。

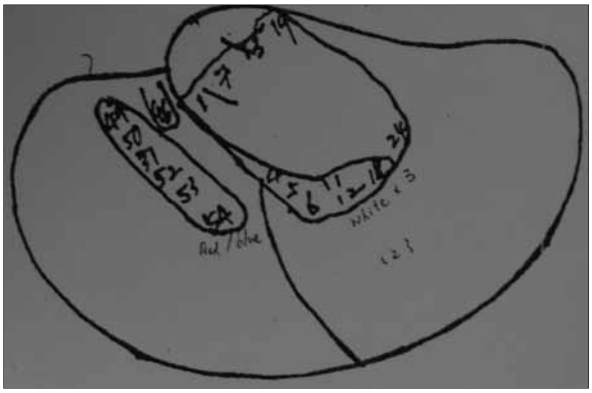

FIG 4. Bursts of paroxysmal fast activity were found followed by background attenuation and then rhythmic discharges from the electrodes 4, 5, and 6 of the subdural grid

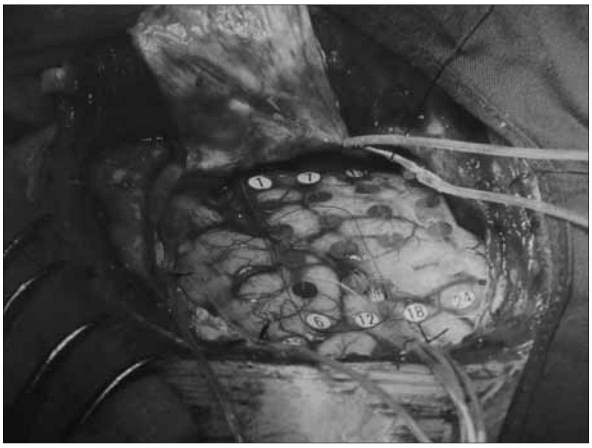

FIG 5. Lateral neocortical epilepsy involving the insular lobe, superior temporal gyrus and inferior frontal gyrus was suspected

by background attenuation and then rhythmic discharges from electrodes 4, 5, and 6 in the subdural grid (Fig 4). Lateral neocortical epilepsy involving the insular lobe, superior temporal gyrus, and inferior frontal gyrus was suspected (Fig 5). The patient was subjected to a second craniotomy during which the entire insular cortex, superior temporal gyrus, and frontal operculum were excised with the inferior margin down to the level of the white matter tract (Fig 6). A histological examination of the excised insular cortex confirmed cortical dysplasia and that of the frontal operculum confirmed microdysgenesis. The patient had an uneventful postoperative recovery with no perioperative morbidity, and has remained seizure-free for more than 1 year.

Discussion

Epilepsy surgery is a treatment modality available for managing patients with medically intractable epilepsy. During the presurgical evaluation, a number of investigations should be done before a patient can be considered an appropriate surgical candidate. The introduction of MEG has been a major breakthrough. This method of detecting magnetic fields produced by cortical neuronal activity was first introduced in 1968.[1] Recordings were initially made using a single-channel induction coil magnetometer but in 1993 whole-scalp MEG instruments were introduced.[1] From this time onward there was more interest in the clinical application of this investigation in neurosurgery.[1] During signal processing, the centre of gravity of the activated area can be located by the MEG dipoles. The time-varying dipole model allows the time behaviour of the brain area to be illustrated with a millisecond scale, and the area with maximal dipoles will be translated to the area of cortex activated simultaneously. Anatomical identification of the area of activation, and measurement of its extent are achieved by attaching head position indicator coils in relation to fixed anatomical landmarks.

Magnetoencephalography and the EEG chart the same neurophysiological processes. They are superior to other non-invasive methods of presurgical evaluation because they provide specific measurements of epileptiform discharges with reference to the brain, and measure the dynamic processes underlying human epilepsy. Magnetoencephalography has these specific advantages compared to scalp EEG[2,3]:

(1) Magnetoencephalography offers better spatial resolution because the magnetic fields are less distorted by resistance from the skull and scalp.

(2) Scalp EEG is sensitive to both tangential and radial components of a current source, while MEG is sensitive to the tangential part only. Magnetoencephalography therefore measures activities only within the sulci.

(3) Magnetoencephalography is primarily sensitive to the magnetic fields generated by intracellular currents, whereas scalp EEG detects extracellular volume currents produced by postsynaptic potentials.

(4) Magnetoencephalography is reference-free, leading to fewer difficulties with data interpretation.

One study showed that MEG and video EEG results were equivalent in 32.3% of patients, and additional localisation information was obtained in 40% of cases by using MEG.[4] A combination of FDG-PET, ictal single-photon emission computed tomography, and MEG before epilepsy surgery allows better patient selection, less risk, and better surgical outcomes.[5-7]

There are about 100 MEG installations available for medical use worldwide. The initial installation cost, which includes a MEG unit, a shielded room and a magnetometer, is over 2 million US dollars. A fully functioning MEG centre requires about 80 litres of liquid helium per week. Normally, an interictal MEG will be performed instead of an ictal MEG because any movement during the ictal period can seriously affect the data acquisition and usability. The risk of performing MEG is similar to that of performing MRI.

Magnetoencephalography can be applied during the presurgical evaluation of different types of epilepsies. Studies have found that it is more sensitive than a scalp EEG for the detection of epileptic discharges from the lateral neocortex. Only 3.5 to 4 cm^2 of synchronised activity is required to produce a detectable MEG signal, whereas 6 cm^2 is traditionally required for a scalp EEG.[8,9] Conversely, in mesial temporal lobe epilepsy, MEG requires an average of 6 to 8 cm^2 of synchronised activity.[8,9] A series that assessed the sensitivity of MEG as a means of detecting specific electric activity during the presurgical evaluation for 455 patients with epilepsy found that it was about 70% sensitive.[10] One study found that its sensitivity was 92% in patients with extra-temporal lobe epilepsy and 50% in patients with mesial temporal lobe epilepsy.[11]

Application of MEG in MRI-negative non-lesional cases provides additional information needed for decision-making, as demonstrated in our case. It helps to localise the epileptogenic zone and delineate the relationship between the suspected abnormality and the relevant regions in the brain. The placement of invasive electrodes can be guided by the MEG findings. Disorders of cortical

FIG 6. Computed tomographic scans showing postoperative images

development, as in our patient, are sometimes difficult to detect on MRI scans. A MEG-guided review of MRI may reveal subtle abnormalities and permit a precise surgical excision of the irritative zone. The rate of positive findings after MEG-guided review of previously MRI-negative films is around 17.5%.[12,13] Magnetoencephalography is also indicated in patients with multiple intracerebral lesions, such as multiple cavernomas, in whom a sole epileptogenic lesion may be identified for lesionectomy.[14]

Current neurosurgical MEG applications are not limited to localisation of the epileptogenic zone. Patients with recurrent seizures after epilepsy surgery usually have scalp scarring and dural adhesion, which hinder the insertion of invasive intracranial electrodes. Shifting of normal brain tissue after resection surgery may cause gross distortions of the topographic anatomy.[15,16] Magnetoencephalography may be considered as a non-invasive alternative; one study proved that MEG agreed well with invasive EEG recordings.[17] Magnetoencephalography also showed a high degree of concordance (87%) with the Wada test in another study.[18] Other possible applications include localisation of the sensorimotor cortex, lateralisation and mapping of speech and memory functions, ictal MEG recordings, and postoperative evaluation of the control of epileptogenic activity.

Conclusion

Magnetoencephalography is an advance in the non-invasive presurgical evaluation of epilepsy patients. Magnetoencephalography and scalp EEG are considered to be complementary and confirmatory to one another, and the localisation accuracy of MEG is comparable to that of invasive intracranial recording. Magnetoencephalography is more sensitive than scalp EEG in neocortical epilepsy. There are drawbacks with MEG however, including its relatively high cost and limited availability in our locality. Application and interpretation of MEG, combined with current methods used to evaluate patients with epilepsy prior to surgery, should provide useful information in the future.

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