Case study

# Right opercular epileptic focus revealed by magnetic source imaging in a patient with implanted vagal nerve stimulator

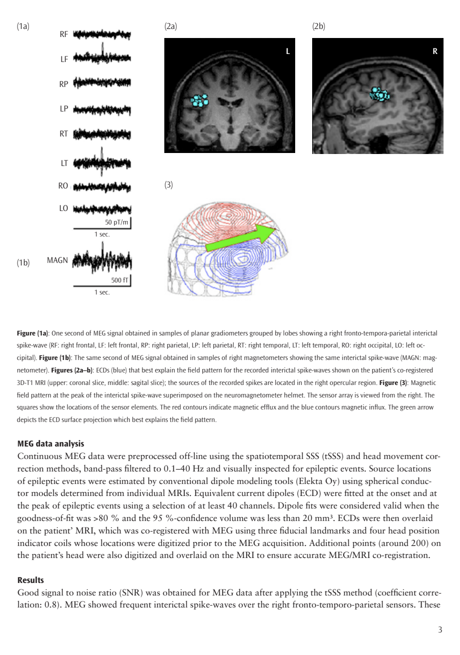

**Figure (1a)**: One second of MEG signal obtained in samples of planar gradiometers grouped by lobes showing a right fronto-tempora-parietal interictal spike-wave (RF: right frontal, LF: left frontal, RP: right parietal, LP: left parietal, RT: right temporal, LT: left temporal, RO: right occipital, LO: left occipital). **Figure (1b)**: The same second of MEG signal obtained in samples of right magnetometers showing the same interictal spike-wave (MAGN: magnetometer). **Figures (2a–b)**: ECDs (blue) that best explain the field pattern for the recorded interictal spike-waves shown on the patient's co-registered 3D-T1 MRI (upper: coronal slice, middle: sagital slice); the sources of the recorded spikes are located in the right opercular region. **Figure (3)**: Magnetic field pattern at the peak of the interictal spike-wave superimposed on the neuromagnetometer helmet. The sensor array is viewed from the right. The squares show the locations of the sensor elements. The red contours indicate magnetic efflux and the blue contours magnetic influx. The green arrow depicts the ECD surface projection which best explains the field pattern.

**MEG data analysis**

Continuous MEG data were preprocessed off-line using the spatiotemporal SSS (tSSS) and head movement correction methods, band-pass filtered to 0.1–40 Hz and visually inspected for epileptic events. Source locations of epileptic events were estimated by conventional dipole modeling tools (Elekta Oy) using spherical conductor models determined from individual MRIs. Equivalent current dipoles (ECD) were fitted at the onset and at the peak of epileptic events using a selection of at least 40 channels. Dipole fits were considered valid when the goodness-of-fit was >80 % and the 95 %-confidence volume was less than 20 mm³. ECDs were then overlaid on the patient' MRI, which was co-registered with MEG using three fiducial landmarks and four head position indicator coils whose locations were digitized prior to the MEG acquisition. Additional points (around 200) on the patient's head were also digitized and overlaid on the MRI to ensure accurate MEG/MRI co-registration.

**Results**

Good signal to noise ratio (SNR) was obtained for MEG data after applying the tSSS method (coefficient correlation: 0.8). MEG showed frequent interictal spike-waves over the right fronto-temporo-parietal sensors. These

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| INSTITUTION: | The Magnetoencephalography Unit, Laboratoire de Cartographie Fonctionnelle du Cerveau, ULB-Hôpital Erasme, Brussels, Belgium |
| PATIENT: | 32-year-old male |
| DIAGNOSIS: | Refractory epilepsy characterized by simple partial seizures with diffuse muscular artifacts |
| INVESTIGATION: | Elekta Neuromag® magnetoencephalography |
| RESULTS: | Magnetoencepahlography localized frequent interictal discharges to the right opercular region and subsequently guided the planning of sEEG |

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# Right opercular epileptic focus revealed by magnetic source imaging in a patient with implanted vagal nerve stimulator

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## Introduction

One of the main interests of magnetic source imaging (MSI) in the non-invasive presurgical evaluation of patients with refractory partial epilepsy is to indicate potential brain regions for further investigations such intracranial electrode implantation. One theoretical limitation of MSI in some patients with refractory partial epilepsy is artefacts generated by implanted magnetic objects such as vagal nerve stimulator (VNS). Indeed, such implanted device generates high amplitude magnetic artefacts during breathing or patient's movements that renders the identification of interictal epileptic discharges impossible due to poor signal to noise ratio.

A new artefact rejection method called spatiotemporal signal space separation (tSSS) method allows almost complete removal of artefacts generated by magnetic objects in movements close to the sensor array. This method is therefore particularly applicable to patients with implanted VNS device.

To illustrate the power of the tSSS* method, we present the case of a patient with a VNS implanted in the context of a non-localizing conventional presurgical evaluation in whom MSI allowed the identification of an interictal epileptic focus in the right opercular region.

## Case report

This 32-year-old man started his epilepsy at age 8 after unremarkable medical history. Seizures were simple partial, characterized by a brief facial contraction followed by an elevation of the superior limbs, and were refractory to valproate, carbamazepine, phenytoin, levetiracetam and benzodiazepines. A conventional non-invasive presurgical evaluation was performed at the ULB-Hôpital Erasme when the patient was 27. Clinical and neurological examinations were normal. Prolonged video-EEG monitoring showed the absence of interictal epileptic discharges and diffused muscular artefacts during seizures. Cerebral structural MRI performed at 1.5 Tesla was normal. Positron emission tomography using [18F]-fluorodeoxyglucose and ictal single photon emission computed tomography were non-localizing. Based on the absence of a good hypothesis for the presumed epileptogenic zone (PEZ), it was decided at the multidisciplinary epilepsy surgery meeting to implant a VNS. Four years later, considering the absence of VNS efficacy, a new structural cerebral MRI was performed at 3 Tesla and was considered as normal. MSI was then undertaken.

## MEG data acquisition

MEG measurements were performed using the whole-head 306-channel Elekta Neuromag® system comprising 204 planar gradiometers and 102 magnetometers. MEG data were acquired in a light-weight magnetic shielded room (MSR, MaxShield™, Elekta Oy, Helsinki, Finland) which combines three magnetic noise suppression methods: 1) a light-weight single-shell shielded room, 2) an active feedback compensation system (three orthogonal coil pairs driven by the MEG sensors) which further reduces the interference at the sensor array, and 3) the software-based signal-space separation method which removes any residual interference (Taulu et al., 2004). Spontaneous magnetic brain activity (eyes-closed rest, supine position) was recorded with MEG for one

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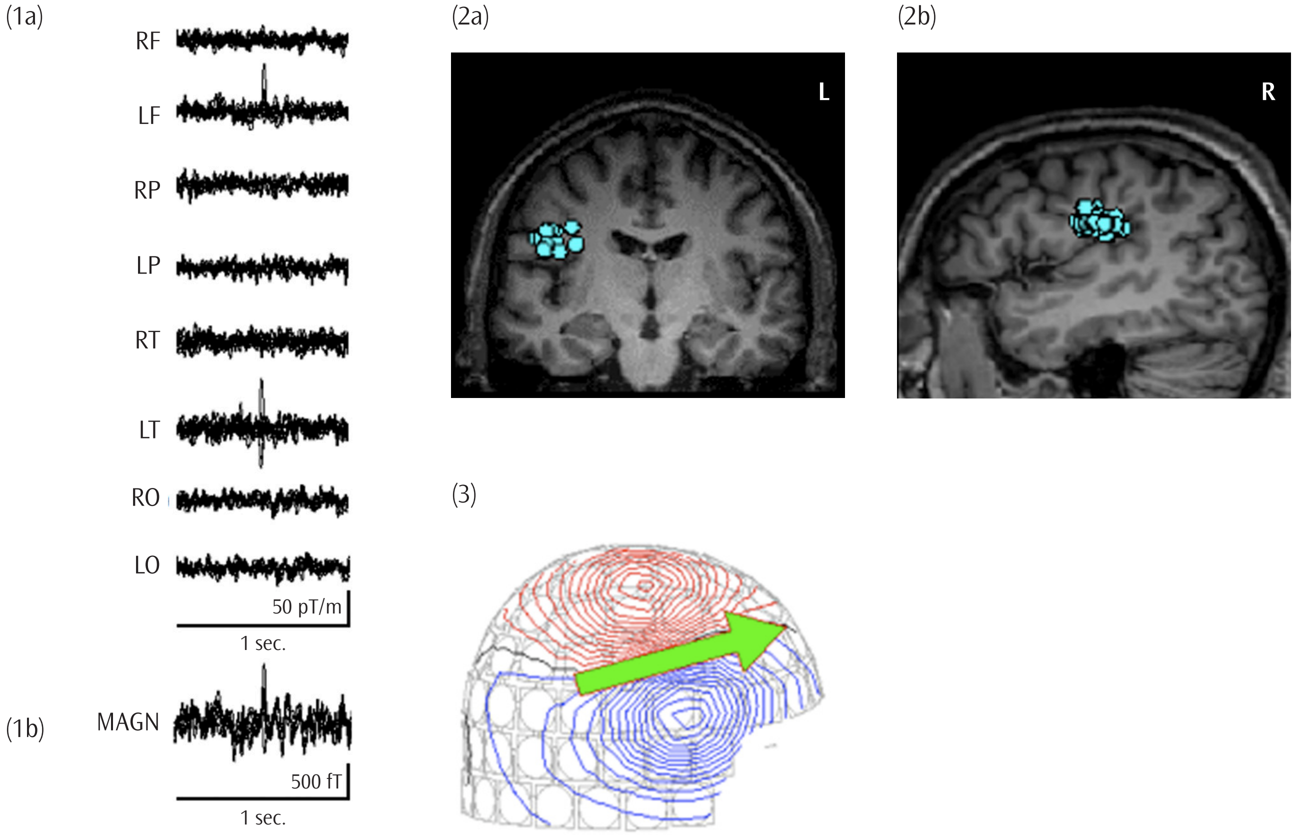
* Spatiotemporal signal space separation (tSSS) is works in progress and not available in the United States.



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hour (sampling frequency 1 kHz, pass-band 0.1–300 Hz). VNS was switched off during MEG data acquisition. Continuous head position tracking was performed during the whole recording.

## MEG data analysis

Continuous MEG data were preprocessed off-line using the spatiotemporal SSS (tSSS) and head movement correction methods, band-pass filtered to 0.1–40 Hz and visually inspected for epileptic events. Source locations of epileptic events were estimated by conventional dipole modeling tools (Elekta Oy) using spherical conductor models determined from individual MRIs. Equivalent current dipoles (ECD) were fitted at the onset and at the peak of epileptic events using a selection of at least 40 channels. Dipole fits were considered valid when the goodness-of-fit was >80 % and the 95 %-confidence volume was less than 20 mm$^3$. ECDs were then overlaid on the patient' MRI, which was co-registered with MEG using three fiducial landmarks and four head position indicator coils whose locations were digitized prior to the MEG acquisition. Additional points (around 200) on the patient's head were also digitized and overlaid on the MRI to ensure accurate MEG/MRI co-registration.

## Results

Good signal to noise ratio (SNR) was obtained for MEG data after applying the tSSS method (coefficient correlation: 0.8). MEG showed frequent interictal spike-waves over the right fronto-temporo-parietal sensors. These epileptiform discharges were best explained by ECDs centred on the right opercular region. Bifrontal stereo-electroencephalographic (sEEG) recording with specific targeting of the right opercular region was planned to confirm the location of the epileptic focus identified by MSI. The patient is on the waiting list for intracranial recording.

## Discussion

This case illustrates that good SNR can be obtained in MEG recordings performed in a light weight MSR in patients with implanted VNS. It also illustrates that MEG may record interictal epileptiform discharges that are not recorded on scalp EEG, due to the fact that MEG is sensible for the detection of tangential (fissural) dipoles. Although the clinical relevance of our MSI finding needs to be assessed by intracranial recording, MSI clearly changed the patient's surgical management in this case by identifying an irritative zone and allowing focal sEEG investigation. In summary, MSI is able to identify potential brain regions for further investigations such as intracranial electrode implantation in epileptic patients even in the presence of implanted VNS.

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