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Feasibility of Magnetoencephalography Recording in an Epilepsy Patient with Implanted Responsive Cortical Stimulation Device

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Approximately 30% of patients with medically intractable epilepsy are not candidates for surgery, and cortical stimulation is a therapeutic option for these patients. The effectiveness of responsive cortical stimulation has been shown in previous studies including a controlled clinical trial (Morrell 2011).

Magnetoencephalography (MEG) is a newer noninvasive tool which can provide accurate source localization of interictal epileptiform activities. Because of its high spatiotemporal resolution and higher sensitivity, it is being increasingly employed in tertiary epilepsy centers. Since MEG is not affected by variations in conduction, and in particular the skull is transparent to magnetic fields, it is especially useful in patients with skull defects due to prior surgery or intracranial evaluation. The MEG signal is, however, easily affected by magnetic noise produced from metal devices. Our previous investigation has shown that spatial temporal filtering was necessary to remove the noise in order to obtain good estimate of dipole localization with vagus nerve stimulators (Kakisaka, et al. 2012). However, to date there is no report on the feasibility of recording MEG from patients with implanted cortical stimulation devices, e.g. the responsive neurostimulation (RNS) system (NeuroPace, Mountain View, California). Since the RNS device itself (i.e. not just the leads) is actually implanted in the skull, rather than at a distance like the vagus nerve stimulation (VNS) device, there has been an open question as to whether successful MEG recordings can be obtained in patients who have RNS implanted.

A right-handed 33-year-old female presented with a history of pharmacoresistant seizures starting at the age of 9 years. Despite a previous right orbito-frontal resection, followed by right frontal lobectomy, her seizures persisted. Surgical pathology did not show any evidence of cortical dysplasia from either surgery. Seizures were axial tonic evolving to

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Conflict of Interest

Cleveland Clinic Epilepsy Center participates in the clinical trial of the RNS@ System. However none of the authors have ties of any kind, or any financial conflict of interest with either Neuropace or Elekta Neuromag.

complex motor, 1-2 times per day, lasting 20-30 seconds. This patient participated in the RNS trial. The RNS® System (NeuroPace, Mountain View, CA), as shown in panel c, provided responsive cortical stimulation via a craniially implanted (right side of the head) programmable neurostimulator connected to a depth electrode inserted into the remaining tissue near the right basal frontal/diencephalon and a subdural strip near the right perisylvian region, over the right precentral gyrus near the face/arm region, where interictal spikes were seen on intraoperative ECoG previously. However, cortical stimulation failed to give improvement of the patient's seizures, and the patient returned for further evaluation to explore possible surgical options. MEG, available in our center subsequent to her previous surgeries, was offered to the patient in an effort to refine the location of her epileptogenic zone and to consider further therapeutic strategies.

Spontaneous MEG data was recorded in a magnetically shielded room using a 306-channel whole-head MEG system (Elekta Ltd, Helsinki, Finland). Signals were sampled at 1000 Hz and bandpass filtered between 0.03 and 330 Hz. We used a temporally-extended signal space separation (tSSS) algorithm, with processing performed by "Maxfilter" software provided from the vendor. Settings included a four-second time window and a subspace correlation limit of 0.9. The tSSS-filtered MEG data were analyzed after digital filtering between 5 and 45 Hz. Technical details of this processing can be found elsewhere (Song, et al. 2009).

Figure 1 shows representative waveforms from the right parietal MEG sensors, before (a) and after tSSS processing (b). Only after preprocessing with tSSS filtering was it possible to perform single dipole analysis of interictal activities; one example is shown in panel d. The dipole source representing this spike was estimated on the previous resection margin (panel e), a typical finding of patients with prior surgery and recurring seizures (Mohamed, et al. 2007). Three types of interictal activities were found as shown in panel g: (1) a tight cluster with uniform horizontal orientation, located in the posterior margin of previous resection; (2) a relatively loose right temporal cluster with varying orientations, in the posterior and lateral temporal lobe and (3) another loose cluster with varying orientations, estimated in the left superior parietal lobe, posterior superior temporal and left insula. Although the first type of epileptic source just posterior to the resected area seemed to be highly consistent and focal, the existence of other active and not very focal epileptic sources in both hemispheres, consistent with video-EEG monitoring, indicated that the patient may not benefit from further surgery.

In summary, we present the first clinical evidence that good-quality MEG data can be successfully recorded with the presence of a RNS device, with appropriate use of tSSS filtering. This result demonstrates that MEG can be an important component during the exploration of surgical options in patients with suboptimal results from RNS.

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Figure 1.

Representative waveforms from the right parietal MEG sensors without (a) and with (b) tSSS processing, displayed on a 10-second page. Location of the implanted RNS device is in the vicinity of the right parietal MEG sensor, as can be seen on the X-ray scans shown in panel (c). No activities can be discerned from panel a, whereas in panel b, a clear epileptiform spike can be seen (enclosed by dashed box). Using equivalent current dipole modeling, this spike is localized to the posterior margin of the previous frontal resection (e). Panel d is the top view image of all MEG sensor activities. The dashed box outlines the area of channels selected to perform the source localization shown in (e), including right parietal and frontal subsets of sensors. On the contour map (f), the green arrow indicates the estimated dipole, the red lines indicate magnetic field efflux from the brain surface, and the blue lines indicate influx. Panel g shows the axial and right sagittal views of all the spike dipoles estimated from the patient's recording. Each of the yellow circles represents the location of a different spike.