Restoration of Visual Field following MEG-guided tumor resection


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1 Introduction

The planning of treatment for structural lesions of the brain is facilitated by knowledge of the function of surrounding brain tissue. Mapping of function preoperatively helps to choose a surgical route to minimize neurologic deficits and define the limits of lesion resectability [1,2]. It also helps in preoperative counseling of the patient regarding the inherent risks. Direct cortical stimulation has been the gold standard for many years [3], but increasingly noninvasive preoperative mapping has been used. Magnetoencephalography (MEG) has emerged as a powerful tool for noninvasive identification of eloquent cortex prior to planned neurosurgical operations [4]. MEG has been validated by several groups for preoperative localizations of sensorimotor cortex [5], visual cortex [6] and language cortex [7].

We report a patient study in which hemifield visual evoked response was used to identify preserved visual pathways in a patient with homonymous hemianopsia due to a cystic occipital mass lesion. This study led to changing the surgical approach to spare visual pathways, which resulted in post-operative restoration of a significant amount of the hemianopic visual field.

2 Methods

2.1 Patient study

Hemifield visual evoked fields [8,9] were recorded with 148 MEG channels (4D Neuroimaging Magnes WH2500). The patient was a 51-year-old right-handed, male with 6-week history of progressive visual impairment produced by a cystic right occipitoparietal brain tumor. On examination, the patient was alert and oriented. Language and speech were normal. Uncorrected visual acuity was 20/30 bilaterally. Pupils were symmetrical and reactive. Extraocular movements revealed a horizontal gaze evoked nystagmus, which was bidirectional. The rest of the neurological examination was normal. Goldman perimetry was used to determine areas of defective vision (Figure 1A).

MEG was ordered to document any residual functional visual cortex. At the time of the MEG study, he had a complete left homonymous hemianopsia. MEG data was collected in the normal fashion [10].

Figure 1 A) Visual deficits prior to tumor resection B) after resection (Left eye fields).

2.1 Data

The visual stimulus consisted of a 0.4 Hz black and white checkerboard pattern reversal image projected into the MSR, via a system of mirrors. The size of the projected checkerboard was 2.5 cm on a side with a visual angle of 11 degrees. The patient was told to fixate on a target at the edge of the image. Two hundred epochs were recorded with a high pass filter of 100 Hz and a sampling rate of 290.64 Hz. Data was forward and backward filtered using a 3-100 Hz bandpass with a 60 Hz notch filter. By visual inspection, major peak latencies corresponding to the n75m, p100m, and n145m were identified and the single equivalent dipoles were calculated. The dipole selection criteria [10] used were 1) correlation coefficient (R) of 0.98 or better, 2) root mean
square (RMS) field values of at least twice the signal strength of the dipole moment (Q), and 3) confidence region (CR) of less than 1.0 cm³.

3 Results

MRI displayed a right occipitoparietal intraaxial mass (Fig. 3A). There was a cystic component with a more superficial solid enhancing component. There was surrounding vasogenic edema. Dexamethasone was used to reduce the edema. A week later, at the time of his MEG study, symptoms had minimally improved and were characterized by occasional perceptions of vague images in the left hemifield. Examination immediately prior to the MEG study showed complete left homonymous hemianopsia.

VEF waveforms were recorded from both hemifields (Fig. 2). The waveforms include 148 MEG channels overlaid; each channel, an average of the 200 pattern reversals. Arrows correspond to the n75m, p100m and n145m peaks respectively. For the right hemifield visual stimulation, waveforms with clearly identified p100m and n145m responses were seen. These localized to the lower lip of the left calcarine cortex with the p100m located just anterior to the n145m. For the p100m the correlation coefficient was 0.99, the confidence region was 0.15 cm³, and the latency was 175 ms. The n75m response mapped just anterior to the p100m, but the best correlation coefficient was only 0.95, and the confidence volume was 9 cm³, making this localization, at latency 108ms, only tentative. For stimulation of the left hemifield, responses were obtained despite the subject’s inability to see in this field. The latencies of the responses were dramatically prolonged and dispersed (Fig. 2) compared to the normal side, with the n75m having a latency of 155 ms, a correlation coefficient of 0.98 and a confidence region of 1.07 cm³. The p100m response to the left hemifield stimulation localized to the right calcarine cortex, almost adjacent to the response of the left hemifield visual stimulation and showed a latency of 0.189 ms, 49 ms longer than the contralateral p100m response. The correlation coefficient was 0.99, and the confidence region was 0.40 cm³. This response localized to the left calcarine cortex but was displaced approximately 3 cm superior and 1 cm anterior to the right hemifield p100m (Fig2A). The p100m was located just mesial to the wall of the cystic lesion in the right occipital lobe. The n145m response to the left hemifield visual stimulation had latency of 242 ms, confidence region of 0.208 cm³, and correlation coefficient of 0.99. It localized just inferior to the p100m on the same side, and again was along the mesial wall of the cystic lesion.

Table 1 lists the dipole parameters for the latencies of interest from the VEF right and left hemifield stimulations. Note latencies correspond to n75m, p100m, and n145m respectively. The n75m (at latency 108ms) in the left hemisphere had a poor confidence region (CR) with low correlation coefficient (R) and low Q value. All other dipoles had values that fell within the preset criteria for reliability.
Figure 3: MRI overlay of the averaged visual evoked field response from the Left hemifield stimulation (Blue Squares) and Right hemifield stimulation (Yellow Circles). A) Coronal slice: 1.3 cm, B) Axial slice: 4.6cm, C) Sagittal slice: 1.5cm.

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<th>Table 1: The dipole fit parameters for the latencies of interest from the left and right hemifield stimulations.</th>
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<th><strong>Right Hemifield stimulation dipole fit parameters</strong></th>
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**Surgical Management and Outcome**

The patient underwent craniotomy for gross total resection of the nodular part of the tumor and drainage of the cyst. Frozen section revealed a pleomorphic xanthoastrocytoma. The remaining occipital cortex was preserved. Post-operatively the patient recovered significant left visual field vision, documented by Goldman perimetry (Fig.1B). The pathology revealed a gliosarcoma within a malignant glioma. Subsequently the patient underwent another right occipital lobectomy, with Gliadel wafer implantation producing a complete left homonymous hemianopsia.

**4 Discussion**

This study demonstrated a normal hemifield response to the visual stimulation of the right hemivisual field. Stimulation of the left hemivisual field in the area of the patient's hemianopsia produced responses markedly prolonged compared to the unaffected side and displaced by the cystic lesion. The displacement of the responses nonetheless showed them to be located along the calcarine cortex, being displaced primarily in the superior direction compared to the normal side.

Preoperative MEG recording of visual hemifield stimulation successfully identified preserved visual pathways in a patient with complete homonymous hemianopsia and provided necessary information to plan surgery which produced a partial restoration of the visual field deficit.

Visual evoked electric response (VEP) to pattern reversal stimulation consists of
presenting black and white checks and monitoring the electric potentials over the occipital area. This response consists of the N75-P100-N145 complex of which the P100 complex is most important. The origin of the P100 complex is believed to be cortical though there is controversy about this [8, 9]. The stimulus could be full field or half field. With half field stimulation, the P100 component of the VEP appeared to be maximal both at the midline and ipsilateral to the half field stimulated. [8]. However interpretation of electrophysiologic recording can be a problem because of dipole orientation and conductance of bone and scalp. For these reasons magnetic visual evoked field response (VEF) has been suggested as a better alternative to localize visual cortex. Comparisons of EEG and MEG, for the study of pattern onset visual response, have demonstrated that visual evoked magnetic fields can be used to validate and extend results of visual evoked potentials.

In our patient the complete hemianopsia on ophthalmological examination would have resulted in an aggressive surgical approach without regard to preservation of vision. However the presence of functional visual cortex in MEG prompted us to approach the lesion with an effort to retain functionally important cortex. The prolonged conduction times through the posterior visual pathways may have been secondary to the peritumoral edema and may have caused visual impairment.

We believe that this is the first report in literature where functional visual cortex was demonstrated in the presence of hemianopsia by noninvasive MEG imaging. The information available preoperatively was used at the time of operation to restore vision.

References