A Multimodal Imaging Approach to Surgical Planning in Temporal Lobe Epilepsy

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Introduction

Functional brain mapping has tremendous potential to guide surgical planning for neurological disorders such as temporal lobe epilepsy (TLE). TLE is a common type of localized seizure disorder, which is often medically intractable [1]. In many cases, surgical intervention provides the best means of seizure control [2]. The challenge in surgery is maintaining balance between removing the damaged tissue (to prevent seizure reoccurrence) and sparing the healthy tissue (to limit functional impairment). The problem is that pre-surgical mapping for TLE must derive clinically relevant data from complex networks that support high level processing. The solution is to selectively evaluate the functional status of a region using a multimodal approach. Preliminary studies have used functional magnetic resonance imaging (fMRI) and event-related brain potentials (ERPs) to map the temporal lobes healthy controls [3,4]. Functional MRI is used in a *site-directed* fashion to test for differences in activation across the lateral and medial temporal lobes. ERPs are used in a *process-specific* fashion to evaluate perceptual and cognitive functioning associated with the temporal lobes. Together, fMRI and ERPs can be used to comprehensively evaluate temporal lobe function in patients prior to surgery. The current study utilizes this approach to develop pre-surgical mapping for TLE.

Methods

Experimental Design: In order to elicit temporal lobe activation, participants performed a control task, a recognition task, and a retrieval task. Stimuli consisted of line drawn objects [5] that were presented centrally. The control task required participants to distinguish real objects from non objects, the recognition task required participants to discriminate living objects from non living objects, and the retrieval task required participants to decide whether they had seen the object in the previous task. Each of the tasks was approximately 6 minutes in length (6 blocks with 10 stimuli per block).

Data Acquisition and Analysis: Functional MRI data were acquired using an asymmetric spin echo (ASE) spiral method [6], which collected two images (each with differing contrast) per slice per volume. Twelve 4 mm axial slices, with a 0.5 mm gap (64 x64 matrix, 240 x 240 mms), were prescribed to cover the temporal lobes. The ASE sequence used an effective echo time (TE) of 25 ms, and a spin-echo centre (TE) of 64 ms, with 2 interleaved shots and a volume repetition time of 2 s (actual TR = 1 s, 186 volumes). For structural registration, a high-resolution spiral out image was collected, with 22 axial slices (128 x 128 matrix, 240 x 240 mm) and 4 interleaved shots. High resolution structural MRI was acquired using a 3D MP FLASH anatomical sequence with TR = 10 ms, TI = 500 ms, TE = 5 ms, 256 x 256 matrix, 3 mm slice thickness and 192 mm phase encode. FLAIR images were prescribed to cover the temporal lobes, with TR = 12 s, TI = 2.55 s, TE = 128 ms, an echo train length of 8, with an effective echo of 4, and 15 ms echo spacing (twenty 3 mm coronal slices, 0.3 mm gap). Functional MRI analyses were performed with a model-based approach (General Linear Model) in FMRIB Software Library (FSL) using fMRI expert analysis tool (FEAT; FMRIB's Software Library). Pre-statistics processing steps included motion correction using MCFLIRT, non-brain removal using BET, spatial smoothing using a Gaussian kernel of FWHM 6 mm, mean-based intensity normalisation of all volumes by the same factor, and highpass temporal filtering. Each task was statistically examined separately for conditional effects as well as conditional differences.

EEG data were acquired using a 64-channel BrainAmp MR system (BrainProducts, GmbH). Impedances were maintained at or below 10 KΩ and the data were bandpass filtered from 0.1 to 250 Hz (5 kHz sampling rate, gain 1000). Continuous data were downsampled to 500 Hz, lowpass filtered off-line to 30 Hz, epoched using stimulus triggers (-100 to 1000 ms), and baseline corrected (-100 to 0 ms). Low-resolution electromagnetic tomography (eLORETA) was used to localize current generators using a spherical head model.

Individuals with epilepsy were compared to matched healthy controls using both fMRI and ERP data in order to examine temporal lobe function prior to surgical intervention.

Results

Figure 1 depicts the fMRI results for a representative patient with epilepsy and a healthy control. Although individual differences are present, both the patient and control data reveal activation in lateral and medial regions on the side of the patient's epileptogenic focus (right). This activation occurred consistently across all three tasks (control, recognition, and retrieval). Figure 2 shows the ERP results for the same patient with epilepsy and a healthy control. In comparison to the control data, patient data showed increased P300 activity during both recognition and retrieval.

Discussion and Conclusions

Preliminary results have revealed that it is possible to evaluate temporal lobe function in patients with epilepsy prior to surgery. The fMRI data indicated active areas in the lateral (i.e. superior temporal gyrus) and medial (i.e. parahippocampal gyrus and uncus) temporal lobe prior to surgery. These regions were comparable to those observed in healthy controls. Pre-surgical mapping with fMRI can provide valuable insight into surgical decisions (e.g., selective amygdalohippocampectomy vs. anterior temporal lobe resection). The ERP data showed intact information processing prior to surgery. However, the increased amplitude and latency of a P300 response suggested that the task was more challenging for the patients with epilepsy (versus healthy controls). These data provide a means of tracking improvements in perceptual and cognitive functions following surgery. In combination, fMRI and ERP data can be used to comprehensively evaluate the functional status of the temporal lobes and consequently, minimize impairments resulting from the removal of tissue in epileptogenic regions.

Figure 1.

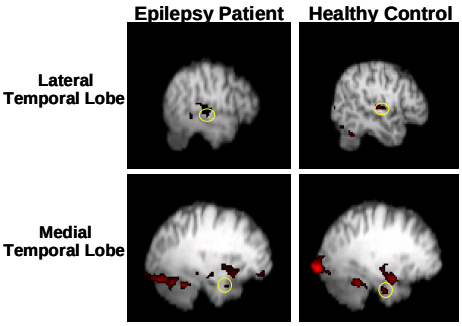
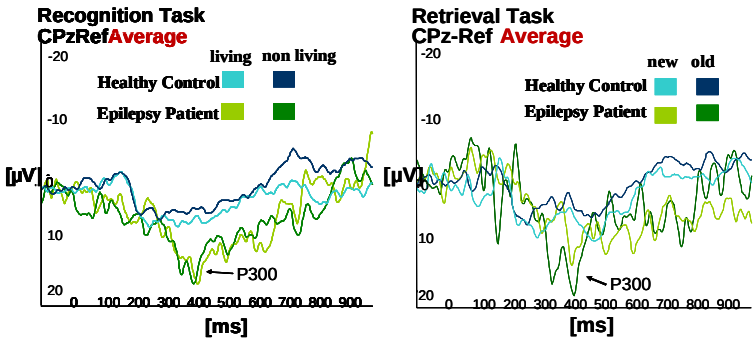


Figure 2.



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