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ABSTRACTS FOR POSTER SESSION ONE

Combinational Imaging: Magnetic Resonance Imaging and EEG Displayed Simultaneously

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We report on a new technique to combine two technologies [magnetic resonance imaging (MRI) and topographic imaging of EEG] to produce an overlapping image of both scalp-recorded EEG and the underlying brain anatomy within a given subject. High-resolution-graphics postprocessing of these data was used to create this integrated image.

EEG is the most widely used tool to assess brain electrical activity. The examination of EEG has been very useful to the neurologist in the diagnosis of epilepsy. However, from the perspective of the neurologist, the EEG suffers from too much information to be realistically managed and evaluated. Thus, the detection of characteristic electrical signatures for disorders other than epilepsy has been largely unsuccessful. EEG imaging techniques have been developed to deal with this problem of data reduction and interpretation. This new methodology can condense, summarize, and display on a color graphics monitor spectral, spatial, and temporal information of brain activity from multiple scalp locations. The product of this automated data handling is a topographic map of electrical activity across the entire scalp. However, the underlying brain anatomical correlates to the scalp-recorded EEG remain obscure. The need for this regional correlation between brain anatomy and function is evident to understand the pathophysiological substrates of abnormal scalp-recorded EEG.

MRI represents an advanced and safe technique used to obtain brain structural information. No attempt has ever been made to integrate these two techniques of functional and structural imaging. The development of a combined imaging technique, using the strengths of each of the available techniques, would provide dramatic new insights into the structural/functional interrelationships of the human brain. There is an expressed need to combine diagnostic techniques to help assess and distinguish between various pathological processes.

We have produced the first combinational image of structure and function of the brain. One normal 37-year-old male, right-handed subject had both MR and EEG imaging, and the separate images were integrated into one overlapping image. Serial, sagittal 5-mm MRI slices, using a partial saturation sequence, were obtained. In order to visualize where subsequent EEG electrodes were to be placed, 28 oil-filled capsules acting as electrode markers were pasted to the scalp using the International 10–20 System of electrode placement. This information was stored on magnetic tape and was taken to the Ohio State University Computer Graphics Research Group for processing.

The MRI data were converted to RGB format for display on a high-resolution-graphics monitor. Each scan line was created, with different gray tones assigned to the MR images. MRI sections showing cerebral cortex were manually traced using the computer cursor to include only the cortex. Each tracing for each of the 28 MRI slices was saved. The brain was reconstructed from these cortical tracings as a three-dimensional perspective image. Perpendiculars were extended from the scalp electrode markers (vitamin E capsules imaged in white) to the underlying cortex to preserve this electrode placement structure on the brain's surface.

The reassembly process of the 28 MRI sections into one three-dimensional MR image involved a technique called *lofting*, which is the construction of a polygonal mesh out of the points in each

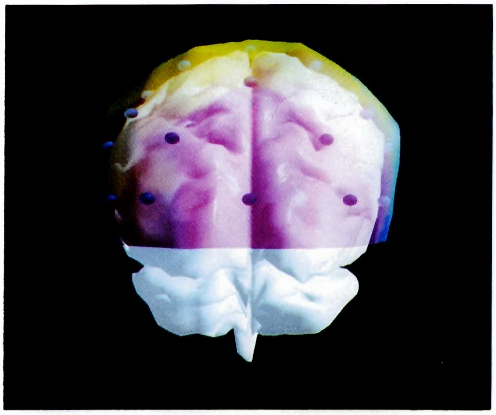

FIG. 1. Posterior view of reconstructed brain from multiple MR images, with color-coded alpha activity recorded from a normal male subject with eyes closed. Electrode positions are marked as blue circles, magenta color is a 50-μV average of 30 artifact-free s of EEG. Note the extensive distribution of alpha activity over occipital, posterior parietal, and left posterior temporal lobes.

slice uniting the vertices and creating thousands of polygons. These polygons described the surface of the brain. Other computer software utilities provided smoothing and shading to the brain image. The final image can be rotated in any axis for facilitated viewing.

The subject then had an EEG performed during an alert eyes-open and eyes-closed state. Artifact-free epochs were analyzed using a fast Fourier transform and converted to spectral maps using a Neuroscience Series II imager. EEG postprocessing involved converting the two-dimensional EEG maps and the electrode markers into a three-dimensional EEG image overlayed to the three-dimensional MR image of the brain. Since the original colored EEG image is an equal-area projection two-dimensional map and since the reconstructed MR image is a perspective image, there were different spatial projection parameters to consider. Instead of a direct overlay of the EEG image onto the MR images, we first overlayed a translucent "skull cap" over the MR image. Then, we used the original EEG microvolt values taken from the 28 electrodes, at a desired time in the data collection epoch, and did a four-point weighted linear interpolation to determine all pixel values within the translucent "skull cap." Various color-blending routines smoothed color transitions from one pixel to the next. This EEG image was made transparent to allow the viewing of the underlying brain. Alpha activity (8–12 Hz), produced while the subject had his eyes closed, was displayed. The highest voltage of alpha activity was seen above visual cortical areas as predicted but extended above posterior parietal and posterior temporal areas more on the left (Fig. 1).

The strength of this new integrated imaging technique is that, if specific regional correlations do exist between brain anatomy and EEG within a given individual, they will now be easily visualized. We believe that the power of this technique lies in: (1) the visualization of brain anatomy in three dimensions, providing easier appreciation for the boundaries of tumors and other anatomical irregularities than in multiple two-dimensional MR slices; (2) the visualization of the precise locations of the electrodes with respect to the underlying cortical tissue within a given subject; and (3) the combined EEG/MR image providing very straightforward correlations between brain structure and scalp-recorded EEG. Future studies will test directly the relationship between: (1) brain tumors and scalp-recorded EEG and (2) localized EEG abnormalities and underlying brain pathology. These studies should lead to a fundamental improvement in our understanding of the meaning of scalp-recorded EEG. Furthermore, these data could lead to an improved system for the placement of EEG electrodes, since their placement with respect to the brain within a given subject will now be known.