Vertex Sharp Waves During Sleep Localized by 2DII

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Abstract

Vertex waves occur most frequently during late stage 1 and stage 2 sleep. They are identified in EEG as distinctive 'V' shaped wave forms with peaks reaching 100-200 μV and with largest amplitude at midline sites when measured with EEG [1,2]. Although vertex waves are easily identified on EEG, they have a more variable appearance on MEG. Patients for pre-surgical mapping are sent to our laboratory for monitoring with 32 EEG electrodes and simultaneous 148 MEG channels for up to 2 hours, during which time many enter stage 1 or stage 2 sleep. Multiple monophasic vertex waves are often identified on EEG recordings. The temporal pattern of the corresponding MEG waveform contains two distinct peaks during the onset of a single vertex wave. Sources of the underlying cortical generators of the vertex sharp wave were modeled using Two Dimensional Inverse Imaging (2DII) [3] and MR-FOCUSS [4]. Magnetic fields associated with vertex sharp waves localized in the superior parietal cortical areas. In terms of hemispheric localization, focal activation was seen in both hemispheres.

1 Introduction

There are currently very few MEG investigations of sleep [5,6,7]. Hughes et al. [5] looked at the relationship between MEG and EEG waveforms of sleep. Lu et al. [6] investigated the underlying neuronal activity during spontaneous sleep. In that study, vertex sharp waves were localized to the inferior parietal area using a single current dipole model with data obtained using a 24-channel SQUID gradiometer. Simon et al. [7] performed an in depth analysis of sleep.

Similar to K-complexes, vertex sharp waves may occur spontaneously or may occur in response to arousing stimuli [8]. In neurophysiologic studies, they have been associated with the N300 and N350 evoked potential responses [9]. Recent EEG studies have attempted to determine the topography of these distinct waveforms and have found that the maximum amplitude of vertex waves localized over midline areas of the cortex [1, 8].

The present study investigated the localization of the vertex waves. Vertex waves are spike-shaped waveforms seen in the EEG leads located in the superior parietal area during late stage 1 and stage 2 sleep [1,10]. Vertex waves are thought to have numerous generators [6] and possibly are secondary evoked potentials of several kinds, most likely auditory [9]. Based on the localization of 33 vertex waves in six subjects, these results support the theory of multiple generators in the parietal cortex giving rise to the large amplitude vertex waveforms seen in stage 1 and stage 2 sleep.

2 Methods

2.1 Patient studies

Six patients (male = 2; female = 4) with histories of localization-related epilepsy (complex partial seizures) were monitored with 148-channel Neuromagnetometer (4-D Neuroimaging Magnes WH2500) and simultaneous 32 channels of EEG (Neuroscan synamps using the 10-20 system).

Each subject changed into a hospital gown and removed all metal articles from his/her body, except for dental work, which was demagnetized with a commercial videotape eraser. Three small electrode coils, used to transmit subject location information to the neuromagnetometer probe, were taped to the subject's forehead with two-sided tape. Disposable ear molds of the correct size were placed in the ears and an additional localization coil was attached to each ear mold. Thirty-three EEG electrodes were glued to the subject's scalp using collodian glue. The subject then lay comfortably on the bed inside the magnetically shielded room, and automatic probe position routines were used to locate the head with respect to the neuromagnetometer detector coils. The neuromagnetometer helmet containing the detector array was then placed over the subject's head in close proximity to most of the cortical surface. The subject was asked to avoid both eye and body movements during data collection. Changes in the subject's position during the study were detected by changes in magnetic field locations from the coils on the forehead and ears. Runs during which the subject moved were repeated.

2.2 Data collection

MEG and EEG data were digitized at 508.63 samples per second from 0.1 Hz to 100 Hz. Three ten-minute continuous acquisitions were collected. EEG was referenced to the POz electrode.

2.3 Analytical Technique

2DII [3] is a current density source imaging technique that produces whole brain images of both focal and extended source structures that may be simultaneously active. The 2DII technique utilizes approximately 3,000 cortical source locations derived from the MRI to model the continuum of cortical gray matter. Utilizing an iterative algorithm the 2DII technique transforms random initial amplitudes of the 3000-point cortical structure into a source structure corresponding to the magnetic field data. To ensure a robust result 20 solutions are used to create the images. MR-FOCUSS [4] utilizes the 2DII source structure and a least squares solution which replaces the minimum norm technique in the FOCUSS [11] iterative algorithm. The localization results are displayed on the volumetric MRI scan.

2.4 Data Analysis

Data were forward and backward filtered using a 3-100 Hz bandpass with a 60 Hz notch filter. Each recording was visually inspected by an experienced clinical polysomnographer who identified artifact free and distinct Vertex waves in each of the 6 subjects. A short interval of time encompassing the Vertex wave was selected and MR-FOCUSS analysis was performed. The waveforms were visually inspected for latency difference between the MEG and EEG vertex peaks. The duration of vertex waves in EEG and MEG was calculated.

MR-FOCUSS current density source solutions were generated for three to twelve vertex waves per patient. The MR-FOCUSS localizations were compared across subjects and within each subject. The location of the epileptic activity was localized for each subject. Amplitude of the underlying current source generating the vertex wave was calculated and compare within each subject and across all subjects.

3 Results

All six subjects fell asleep and entered stage 2 sleep. Vertex waves were easily identifiable in the EEG traces and the peak latency was used to identify the peak vertex wave in the MEG data. A total of 33 vertex waves were seen in six subjects. A total of 3-12 vertex waves were identified in each subject. A Vertex waveform is shown in Figure 1. The MEG, and EEG traces in figure 1 displays the ease of identifying a vertex wave in EEG recordings.

The average individual MEG vertex wave peak latency, difference between EEG and MEG, source location, and underlying source amplitude are displayed in Table 1 for all patients along with their epileptic foci localizations. MR-FOCUSS source localizations for all patients found the generators of the underling source in the parietal cortex.

There was no time lag between the peak of the vertex wave in the MEG and the EEG data. Average duration of the vertex wave in the MEG was 152 ± 50 ms. The overall average of the underlying source for the vertex waves was 2.7± 2.2 nAm. The amplitude of the average epileptics spikes were 187± 54 nAm. In each subject location of neuronal activity for Vertex waves were found in either hemisphere. Figure 2 depicts the MR-FOCUSS localization for the peak of one vertex wave in subject 1.

Table 1 S = Subject, LD= latency differences between Vertex peak in EEG and MEG data, SA = source amplitude of underlying neuronal activity, HL= Hemisphere Location, R = right, L= left.

Table I

S	LD (ms)	SA (nAm)	HL epileptic focus	HL vertex wave
1	0	3.9 ± 4.2	Left temporal	R-3; L-2
2	0	2.4 ± 0.7	Left frontal	L- 4
3	0	5.1 ± 4.5	R and L	R -1; L-2
4	0	2.2 ± 0.1	Left temporal	R-1; L-2
5	0	0.9 ± 0.6	Left	R-5; L-1
6	0	3.0 ± 0.5	No spikes	R-2; L-2

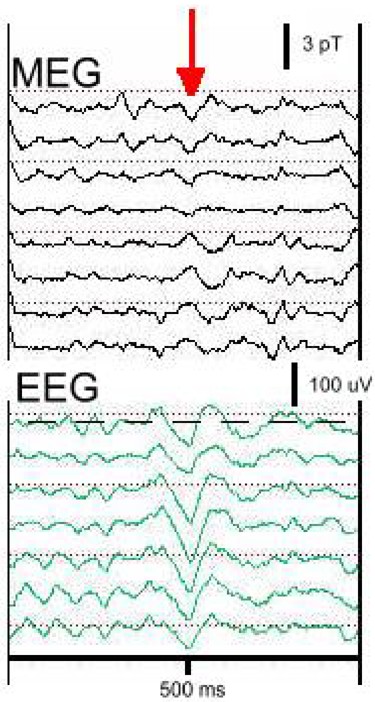

Figure 1: The MEG and EEG waveforms of a vertex wave. Arrow denotes peak of the waveform.

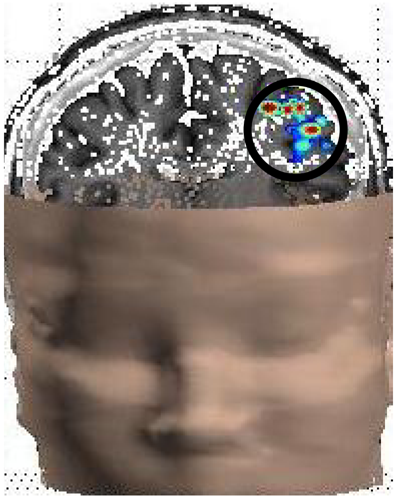

Figure 2 Vertex wave localization in one subject. Circle indicates most intense area of cortical activation.

4 Discussion

Vertex waves can be identified in MEG data. We localized extended areas of neuronal activity in the parietal region in all subjects. This supports the theory of multiple generators as the underlying source for these large waveforms.

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