Magnetoencephalographic Measurements of a Developing Infant: A Pilot Study

Bowyer, S.M.[1,2], Moran, J.[1] and Tepley, N.[1,2]

[1]*Henry Ford Hospital, Detroit, MI, USA;* [2]*Oakland University, Rochester, MI, USA*

Introduction

MEG time-series recording of spontaneous activity is being used in our laboratory to study the adult brain in association with the mechanisms for stroke [7] and Migraine [9, 1]. In the present study MEG is used to study the development of the Central Nervous System (CNS) in a developing infant. In the past electroencephalography (EEG) has been used for similar studies. EEG has recorded the organization of the frequencies associated with CNS development [2, 4, 6]. MEG studies are much more easily conducted on a sleeping infant. One feature of the data obtained, sleep spindles are bursts of activity in the 11-15 Hz range lasting from tenths of seconds to approximately four seconds [5]. Sleep spindles of early childhood first occur during the third month of life and are an indication of normal sleep patterns being established. This particular activity in the 11-15 Hz tends toward an adult 14 Hz rhythm between 18 and 24 months of age, when a more mature (shorter spindle train length with a less spike-like negative component) sleep spindle activity is developing [3]. Early childhood sleep spindles have been seen on EEG and are considered to be a good indication of a normal developing Central Nervous System [6, 8]. Sleep spindles are observed in the frontal or central cortex during stage 2, and stage 3 sleep [5]. There tends to be an asynchrony in the appearance of sleep spindles between hemispheres in infants under one year of age [6, 8]. The absence or decrease of early childhood sleep spindle activity indicates an abnormality of the CNS such as cerebral dysfunction [3, 6, 8]. A second feature of the data obtained is the low frequency activity in the 4-10 Hz range. Low frequencies tend to decrease over time in the maturing CNS [5]. Magnetoencephalographic measurements were performed on a developing infant during this longitudinal study.

Method

The subject was a healthy male, full-term, infant (birth weight: 6 lbs. 4 ozs.). There were no known abnormalities or defects of the Central Nervous System and no family history of neurological disease. No medication was administered at any time during the study. Informed consent was obtained from the parent.

The subject was studied once a week from 18 weeks of age to 65 weeks of age. During the first half of the study, from 18 to 43 weeks of age, mother's milk was used to nurse the infant to sleep. Formula was used thereafter to nurse the infant to sleep (44 to 65 weeks). After he fell asleep the infant was placed under a 7 channel Superconducting Neuromagnetometer (Bti model 607), inside of a magnetically shielded room. The probe was positioned over the left hemisphere of the head first then over the right hemisphere. In reference to the International 10-20 system of electrode placement, the central coil in the 7 channel array was centrally located over the frontal-central region in the T4 location on the right side and in the T3 location on the left side of the head. (Fig. 1) Six minutes of data were collected on one side of the infants head. He was then rotated 180° and repositioned under the probe while he slept. Three more minutes of data were collected on this side for a total of six minutes of data. Data was stored on optic disk for analysis later.

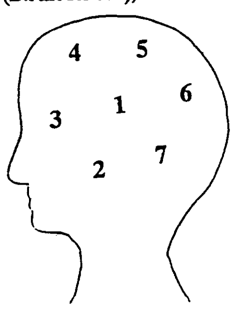

Fig. 1 Magnetometer channel locations

Results

Only the data for the channel over the frontocentral region of the infant's brain was used. This was where the sleep spindles were most prominent. Fig. 2 and 3 display the real time data showing typical sleep spindle bursts (underlined) as their length decreased over time.

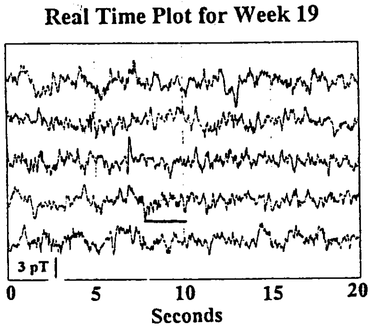

Fig. 2 Raw data collected from the right hemisphere during week 19. Each horizontal line represents 20 seconds of continuous data. The above plot represents 80 seconds of data. The sleep spindle burst is underlined.

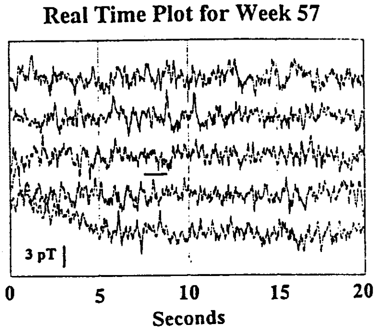

Fig. 3 Raw data collected from the right hemisphere during week 57. Each horizontal line represents 20 seconds of continuous data. The above plot represents 80 seconds of data. The sleep spindle burst is underlined.

Fig. 4 and 5 are FFTs performed on week 19 and 57 showing the peak frequency increased from 13.23 Hz in week 19 to 14.04 Hz in week 57.

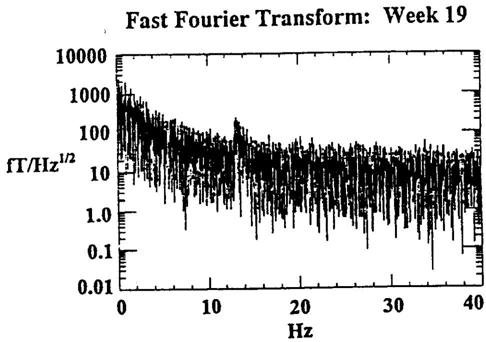

Fig. 4 FFT of data for week 19

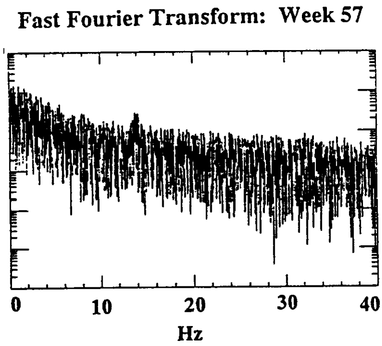

Fig. 5 FFT of data for week 57

The six minutes of data were broken up into 18 epochs of 20 seconds, each was spectrally analyzed by a Fast Fourier Transform (FFT). Analysis was performed on the frequency range from 3.5 Hz to 15.5 Hz. The data was converted into a percentage of the daily spectrum. An overall time averaged FFT was obtained. The average of the sequential FFTs was used to quantify the spectrum for each date. To quantify the changes in the study we calculated the percent changes in the relative spectral composition of the daily spectrum from this average spectra. The Frequencies were classified into two ranges (4-10

Hz) and 11-15 Hz) and these bands were grouped together and graphed over time. Linear regressions were plotted over the data spectra. A linear increase in the percent change over time was found for the frequency range 11-15 Hz and a decrease for the frequency range 4-10 Hz. These findings were significant in each hemisphere and for both frequency ranges: sleep spindle band (11-15 Hz), and low frequency (4-10 Hz). Table I displays the correlations and significant p-values.

TABLE I

		correlation	p-value
Sleep spindle 11-15 Hz:	Right hemisphere	0.504	0.002
	Left hemisphere	0.523	0.003
Low Frequency 4-10 Hz:	Right Hemisphere	0.578	0.0003
	Left Hemisphere	0.589	0.0005

Fig. 6 through 9 display graphically the percent change over time of the daily averaged FFT from the overall time averaged FFT.

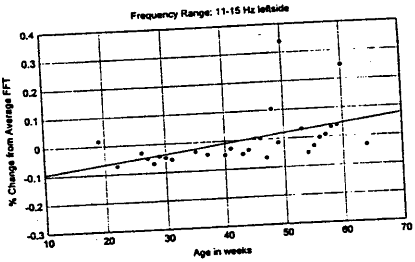

Fig. 6 Percent change in Sleep spindle activity of the left hemisphere.

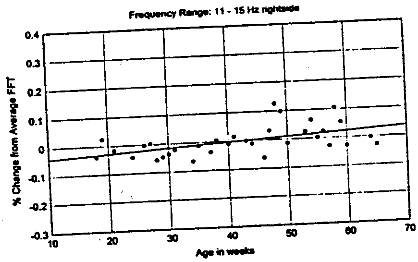

Fig. 7 Percent change in Sleep spindle activity of the right hemisphere.

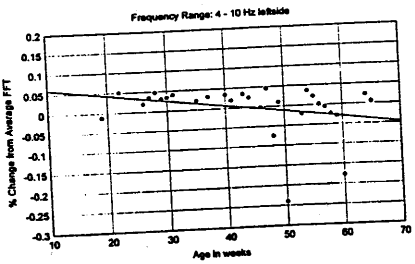

Fig. 8 Percent change in Low Frequency activity of the left hemisphere.

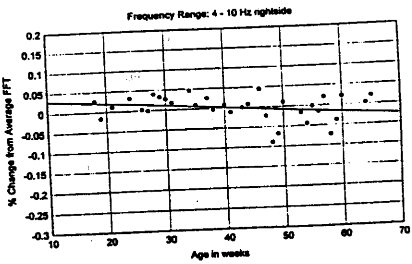

Fig. 9 Percent change in Low Frequency activity of the right hemisphere.

Discussion

Magnetoencephalography can be used to determine the significance of the CNS developments over time in a developing infant. This procedure has a number of advantages over

Electroencephalography. MEG is less time consuming; it takes approximately 20 minutes to place a full array of electrodes on an infant, while it takes less then 2 minutes to position the probe over the area of interest on the infants head. Electrodes are not required to collect data for MEG making it easier for the technician to prepare the infant for the study. Infants can peacefully fall asleep as opposed to being forcibly restrained in papooses used to facilitate the electrode placement. In papooses they tend to scream and cry placing undue stress on them prior to the studies.

The results showed a difference in the increase and decrease of the linear regressions from hemisphere to hemisphere. These results can be explained by observing that the infant was always studied on the left side first. During this time he was most likely entering into a state of arousal conducive to sleep spindle activity. (i.e. light sleep, stage 2) During the second half of the study he fell into a deeper sleep in which sleep spindle activity decreases or ceases. Since we cannot collect simultaneous data on both sides of the head we are unable to make a conclusion regarding the asyncronisity of sleep spindle appearance.

The data in this study was based on 6 minutes of light, daytime sleep and can not truly be compared to the over-night studies completed in EEG. In addition the stages of sleep were not scored. One of the purposes of this study was to see if the results from prior EEG studies could be replicated. We have shown that similar results can be obtained using MEG. These developmental changes need to be further studied to determine their significance over a larger sample. To the best of our knowledge this is the first study of this kind performed on MEG. This can be a clinically useful technique for obtaining information about the developing Central Nervous System.

Acknowledgment

Thank you to Michael for being a good subject, and to Uma Saligram and Yeaton Clifton for their help in collecting the data. This research supported by NIH/NINDS Grant No 1R01 NS30914

References

[1] Barkley, G., Tepley, N., Nagel-Leiby, S., Moran, J., Simkins, R., Welch, K.M.A. Magnetoencephalograhic Studies of Migraine. Headache Journal, 1990; 30 (7), 428-434.

[2] Ellingson, R. Development of Sleep Spindle Bursts During the First Year of Life. Sleep, 1982 5 (1): 39-46

[3] Jankel,W.R., Niedermeyer, E. Sleep Spindles. Journal of Clinical Neurophysiology, 1985, 2 (1): 1-35.

[4] Louis, J., Zhang, J.X., Reuol, M., Debilly, G., Challamel, M.J. Ontogenesis of nocturnal organization of sleep spindles: a longitudinal study during the first 6 months of life. Electroencephalography and Clinical Neurophysiology, 1992, 83: 289-296.

[5] Niedermeyer, E. Lopes Da Silva, F. Electroencephalography, Basic principles, clinical , applications and related fields, Maryland, Williams and Wilkins 1993.

[6] Shibagaki, M. Kiyono, s., Kazuyoshi, W. Spindle Evolution in Normal and Mentally Retarded Children: A Review. Sleep, 1982, 5 (1): 47-57.

[7] Tepley, N. Spreading Cortical Depression and Related DC Phenomena, In: Hoke, M., Ernd, S. N., Okada, Y. C., Romani, G. L. Biomagnetism: Clinical Aspects, Amsterdam, Excerpta Medica 1992, 329-335.

[8] Tyner, F. S., Knott, J.R., Mayer, Jr., W. B. Fundamentals of EEG Technology. Volume 1: Basic Concepts and Methods. New York, Raven Press p 242-245.

[9] Welch, K.M.A., Barkley, G., Tepley, N., Ramadan, N., Central Neurogenic Mechanisms of Migraine. Neurology, 1993; 43 (suppl 3): S21-S25.