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Frequency-specific blocking in the human brain caused by electromagnetic fields

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BASED on preliminary observations that continuous exposure to electromagnetic fields (EMFs) produced an after-effect on human brain electrical activity, the effect of 10 Hz, 1 gauss, on the intrinsic activity of the brain at that frequency was studied. Ten subjects were exposed for 10 min and the 10 Hz spectral power was measured during the 1 min interval following stimulation and compared with control values obtained from the same subjects. Significantly reduced brain electrical activity from the occipital electrodes following termination of the EMF exposure was observed, thereby confirming the preliminary results.

Key words: EEG; Electromagnetic field; EMF; Magnetic field; Brain; Power spectra; Fourier transformation

Introduction

We previously reported that application of electromagnetic fields (EMFs), 0-60 Hz, 0.2-1 gauss, altered brain electrical activity in animals and human subjects[2,3] during 2 s exposure epochs. The effect was observed in most subjects, thereby indicating that the ability to detect weak external EMFs is a general physiological property. The exposed and control epochs were separated by 5-8 s to permit the brain to recover its intrinsic brain electrical activity following presentation of the EMF, but preliminary observations during those studies suggested that significantly longer exposure times produced an after-effect on brain activity. This study was therefore performed to determine whether continuous exposure to EMFs for 10 min resulted in a detectable persistent change in brain electrical activity following termination of the field. We report here that, on average, the 10Hz component of the electroencephalogram (EEG) was partially blocked by 1 gauss (G), 10Hz, as manifested by a reduced value of the 10Hz spectral power from the period following termination of the field.

Materials and Methods

Magnetic fields were produced using Helmholtz coils as described previously;[1,2] the subjects sat between the coils on a wooden chair in a dark, sound-proofed room with their eyes closed. The head and upper chest were within a field region that was uniform to within 5% of its predetermined value; the average background 60 Hz magnetic field was about 0.1 mG. The equipment that powered the coils and recorded the EEG was located 15 m from the room occupied by the subjects. There were no visual, auditory or tactile cues to the subjects that indicated the presence of the magnetic field. The component of the static geomagnetic field parallel to the 10 Hz field was 224 mG.

Ten subjects, four males and six females, 30-51 years of age were studied; eight were chosen from the general population, and two were selected from those who underwent a clinical EEG as a diagnostic procedure. The subjects were told that the EMF would be applied during the test session, but they were not told of either the duration or the timing of the application of the field. All subjects signed an informed-consent form approved by the Institutional Review Board of the Louisiana State University Medical Center. Both clinical EEGs contained intermittent, dysrhythmic activity, but the effects of the EMF were analyzed without respect to age, sex, or the presence of symptoms.

Gold-plated surface electrodes 1 cm in diameter (Grass Instrument Co., Quincy, MA) were placed at C_3, C_4, P_3, P_4, O_1 and O_2 (10—20 system) referred to linked ears; the ground was placed on the forehead. The EEG was measured during four time periods in each test session; the signal was filtered to pass 0.3—35 Hz and then split and simultaneously recorded on an electroencephalograph (Model 6, Grass Instrument Co., Quincy, MA) and stored after sampling at 200 Hz.

A sinusoidal field of 1 gauss (rms), 10Hz, was applied continuously to each subject during a 10 min interval in the middle of a 32 min test session, and the EEG was recorded after the exposure period and at three other times during the test session (Fig. 1). For each time period, Fourier transformations were performed on 30 consecutive artifact-free 2 s epochs and the 10Hz spectral power thus obtained was averaged, and then analyzed to determine the effect of the EMF. The 10 Hz power measured during the period immedi

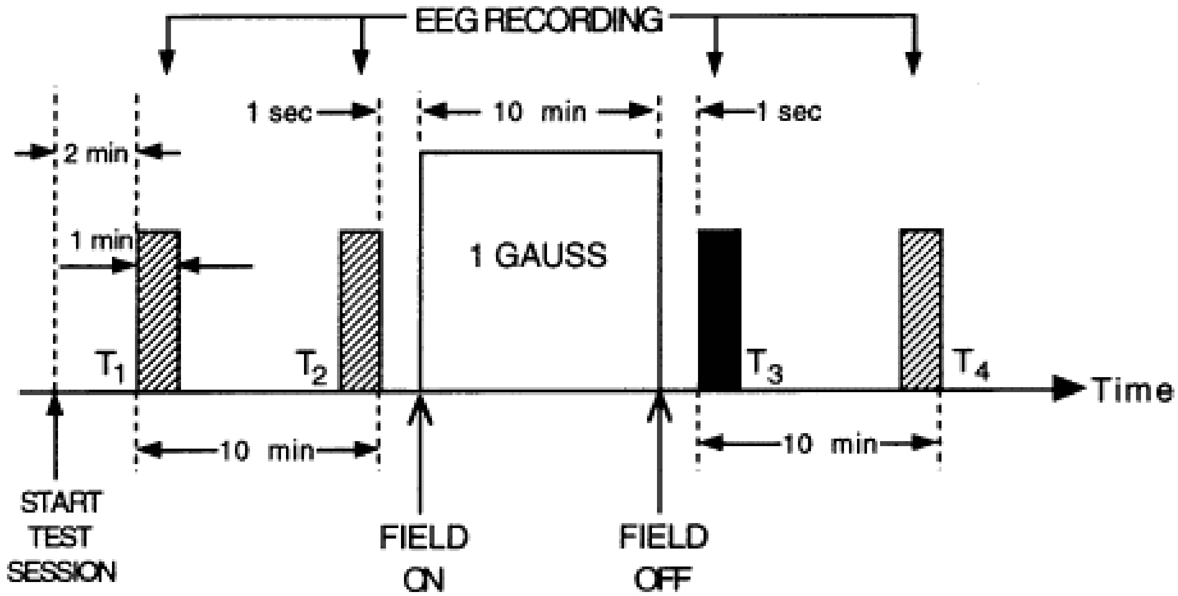

FIG. 1. Relationship between applications of EMF and EEG sampling. The EMF was applied continuously for 10min and the 10 Hz power was determined from the EEG measured prior (during T_1 and T_2) and subsequent to (T_3 and T_4) application of the EMF. The sampling interval hypothesized to contain the after-effect of the EMF is indicated by the black bar.

ately after EMF exposure (T_3) was compared with the mean from the three other values obtained during the test session (average of T_1+T_2+T_4). The data were tested for normality using the chi-squared test, and for differences between the exposed and control periods using the paired t-test. Separate t-tests were performed using the mean values from each of the three pairs of electrodes, and the familywise error was controlled using the Bonferroni procedure,[4] with the comparison-wise error rate set at 0.05/3=0.017.

Results

Brain electrical activity recorded from the C and P electrodes immediately following application of the EMF (during T_3) did not differ significantly from the control value obtained from three representative 1 min periods during the test session. However, electrical activity recorded from the 0 electrodes was significantly reduced as a consequence of EMF exposure (Fig. 2). When the power from T_3 was excluded from consideration, no significant differences were found between any two 1 mm periods or between any one period and the mean from the remaining two periods, for either the C, P or O electrodes.

Discussion

Averaging of the EEG over 1 min is sufficient to permit analysis of the effects of disease, age and other fac

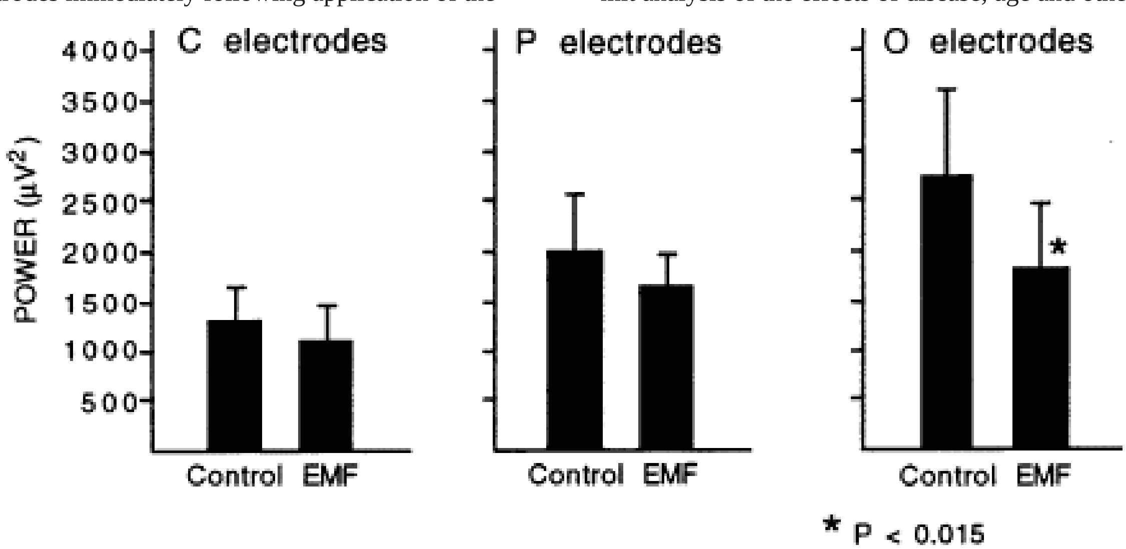

FIG. 2. Effect of EMF on brain electrical activity. The control values were obtained by averaging the 10Hz spectral power from T_1, T_2, and T_4; the EMF values were obtained from T_3. The error bars indicate standard errors.

tors,[5] and it therefore seems likely to have been sufficient for analyzing the effects of EMFs. Possible effects of fatigue or boredom on the subjects were controlled by sampling the EEG before and 10 min after termination of EMF exposure, and including the corresponding measurements in the control value. When the values of spectral power from T_1, T_2 or T_4 were compared with one another or with the average of the other two values, no significant differences were observed. This result suggested that neither the stochastic nature of the EEG[6] nor the possible effects of fatigue were likely explanations for the observed difference between the 10Hz power in T_3 and the control value, although the possibility that the result was due to chance cannot be excluded.

Light and somatosensory stimuli produced enhanced brain rhythms after termination of the stimuli.[7] Similarly, spectral power was increased following 10 mm exposure to a static EMF of 2000 gauss.[8] In distinction to these reports, the effect of 1 gauss on brain electrical activity reported here was a decrease in spectral power after termination of the stimulus. A reduction in electrical activity was observed previously during application of 35—40 Hz, 0.25—0.5 gauss.[2]

EMF-induced changes in activity recorded during relatively brief application of the field occurred more often at the central and parietal electrodes than at the occipital electrodes? In contrast, the EMF-induced after-effect reported here was statistically significant only at the occipital electrodes. This may indicate that the duration of the stimulus affects either the locus of transduction or some aspect of the subsequent processing of the afferent signal. However, activity was decreased at all electrodes (Fig. 2), and it is possible that a slightly larger number of subjects would have resulted in significance at the other sites. Thus, the observation that the response was more intense over the visual area of the brain may simply be a reflection of the number of subjects studied.

Conclusion

A weak EMF applied continuously to human subjects for 10mm resulted in a reduction in brain electrical activity at the frequency of the EMF during the 1 min interval following termination of the field. This result differed from the after-effect on brain activity caused by light, somatosensory stimuli, or strong EMFs reported by others, which consisted of increased electrical activity after termination of the stimulus. The EMF-induced after-effect reported here occurred at the occipital electrodes, in contrast with effects recorded during presentation of the EMF described previously, which occurred mainly at the central and parietal electrodes.

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