BE-10

EFFECTS OF RADIO FREQUENCY FIELDS ON THE EEG OF RABBIT BRAINS

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Previously we reported that chronic exposure of rabbits to RF energies produced abnormal EEGs. We further reported that the type of abnormal EEG depended on the intensity of RF fields. Namely, increase of slow waves with moderate RF intensities and appearance of fast waves with low intensity fields.

We repeated previous experiments using similar conditions and confirmed the appearance of abnormal EEGs. In particular, after long irradiation at low intensities (100-200 V/M), the EEG is characterized by the presence of spindle-like signals with a frequency about 14-16 Hz. These spindles have large amplitudes and appear with a mean interval of 20-30 seconds. These abnormal EEGs persist for several weeks even after the termination of irradiation.

In order to locate the source of abnormal spindles, we used three intracranial electrodes in the posterior regions of both hemispheres and the ground electrode in the anterior region on the midline. Using these electrodes we found that the spindles are originating from the posterior region of the right hemisphere. This observation indicates that the lesion caused by RF is limited to a small region of the brain.

The effects of acute irradiation on EEGs were reinvestigated using an improved technique. RF pulses (1 ms with an interval of 1 second) were applied to animal heads. EEG recordings were initiated immediately after the end of each pulse and continued until the arrival of another stimulus. We found that RF pulses eliminated the normal patterns and replaced them with low amplitude fast waves with frequencies 15-25 Hz. These abnormal patterns are transient and disappear in several minutes if the field is terminated. In spite of these observations, these experiments failed to detect a well defined time locked evoked signal as a consequence of RF stimuli.

Previously, we reported that acute irradiation of rabbit brains with low RF energies had no tangible effects on their EEGs and that only chronic exposure of animals to those fields produced abnormal EEG signals. We further reported that the type of abnormal signals depended on the power or intensity of RF fields, i.e., low intensity RF produced fast waves while high intensity fields enhanced slow components between 4-5 Hz.

In spite of the appearance of marked abnormalities in irradiated brain EEGs, it was still difficult to establish the causal relationship between RF stimuli and signal changes. These uncertainties prompted us to repeat previous experiments under similar conditions.

First of all, using the same carrier and modulation frequencies (1.2 MHz and 14 Hz) with, however, slightly higher intensities, we reproduced abnormal EEGs after chronic irradiations for 8-9 weeks. The abnormal EEGs consist of high frequency background waves (low amplitude) and intermittent appearance of high amplitude spindle-like signals. Spindles have very high amplitudes and frequency of 14-16 Hz. The duration of spindles is usually 1-2 seconds and interval between them is 20-30 seconds. However, duration and interval of spindles are random and we could not detect periodicity.

We noted that the frequency of spindles (14-16 Hz) is close to the modulation frequency (14 Hz). This observation raises a question whether or not the spindle frequency is a direct consequence of modulation frequencies. In order to confirm this, we are currently investigating the effect of modulation frequencies by changing them systematically between 10 and 20 Hz.

In the previous experiments, normal as well as abnormal EEGs were recorded using two macro electrodes (radius 6 mm) which were placed on the skull in the anterior and posterior regions on the midline. Since these electrodes cover a large area, we could not locate the source of abnormal EEGs, particularly the spindle generator. There are actually two possibilities. 1) RF affects brain tissues and their activities diffusely, and 2) RF causes lesions in a small area of a particular region. In order to probe this problem, we used three small electrodes which are placed intracranially in the posterior region of right hemisphere (A), posterior region of left hemisphere (B) and finally a ground electrode in the anterior region on the midline (C). We found that spindle-like signals can only be recorded using electrodes A(+) and C(-). Recordings with B(+) and C(-) indicate that the signals are quite normal. These results indicate that the source of spindles is located in the right hemisphere. Furthermore, when the polarity A(-) and C(+) is used, we observed spindles with, however, an inverted polarity. Namely, sharp spikes downward and blunt side upward. From these observations, we concluded that the source of spindles is located in the posterior region of the right hemisphere.

We are currently repeating similar experiments in order to investigate whether the radiation creates the source of abnormal EEG signals in a particular region of the brain or the location of these sources changes from one animal to another. Should the spindle source be created at the same spot each time, this would mean that there is a part of the brain which is particularly receptive to RF radiations. On the other hand, if the source is found at different sites each time, this would mean that RF radiation causes lesions non-selectively. At any rate, it is likely that the lesion caused by RF radiation is limited to a small area.

Although we previously reported that acute irradiation did not produce tangible effects on EEGs, we decided to reinvestigate this problem using an improved technique. Previously, rabbit heads were irradiated by RF for two to three hours and the recording of EEGs was started after the irradiation was terminated. In the new experiments, pulsed RF fields (duration 1 ms, interval 1 second) are applied to rabbit heads using aluminum plates without direct contact with the animal. EEG recording was initiated immediately after the end of each pulse and continued until the arrival of the next stimulus. Since the duration of RF pulses is short and interval between pulses is much longer, temperature rise due to these pulses can be considered negligible. EEGs were recorded as before using a pair of skull electrodes.

The results of these experiments can be summarized as follows. 1) Application of RF pulses eliminated the normal EEG (5-10 Hz) and replaced them with small high frequency waves (15-20 Hz). These fast waves disappear within several minutes if the fields are turned off. 2) RF pulses did not produce time-locked evoked potentials. Evoked potentials are usually recorded after stimulation of sensory organs. We failed to observe 'evoked potential' as a consequence of RF stimuli applied directly to animal heads in spite of the use of signal averaging technique. The first results indicate that acute irradiation indeed changes EEG patterns and produces fast waves. These abnormal signals are, however, transient and disappear quickly if the irradiation is terminated. The second results suggest the difficulty of establishing the causal relationship between RF stimuli and brain signals.

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