Electrocorticographic Changes in the Rabbit during and after Fractionated X-irradiation

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(Received Feb. 20, 1973)

ABSTRACT

The effects of fractionated X-irradiation on the spontaneous electrical activity in the visual cortex were studied in four adult male rabbits with permanently implanted electrodes. Two of the rabbits received a dose of 300 R and two a dose of 1500 R, fractionated into 50 and 150 R per day administered at semi-weekly intervals. The head, except for the region of brain, was shielded with a lead plate. The electrical activity was averaged with a CAT 400 B. The obtained averaged electrocorticograms were classified into seven waves: \( \delta_2 \), \( \delta_1 \), \( \theta \), \( \alpha \), \( \beta_1 \), \( \beta_2 \) and \( \beta_3 \) by means of an EEG frequency analyzer. The amplitude of the \( \delta_2 \), \( \delta_1 \), \( \theta \), \( \alpha \) and \( \beta_1 \) waves of the two animals irradiated with 1,500 R gradually decreased with increasing doses during fractionated X-irradiation. The decreased value remained relatively constant throughout the observation period after the end of exposure. The two animals irradiated with 300 R did not show any definite changes in amplitude during and after fractionated irradiation. The results are discussed in reference to the findings of the previous study using photic stimulation.

INTRODUCTION

In a previous paper we have reported the electrophysiological changes in the visual cortex of the rabbit during and after fractionated X-irradiation from estimation of the photic evoked potentials. The present paper describes a study of the electrocorticographic changes in the visual cortex of rabbits during and after fractionated X-irradiation.

MATERIALS AND METHODS

Four adult male rabbits were used in this experiment. They were part of an-
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...mals described previously\textsuperscript{1}). Animals No. 399 and No. 400 were irradiated at semi-weekly intervals with 150 R for 5 weeks while animals No. 424 and No. 441 were irradiated at the same intervals with 50 R for 3 weeks, resulting in cumulative doses of 1,500 and 300 R, respectively. The head, except for the region of brain, was shielded with a 4 mm thick lead plate. Details of experimental methods were described elsewhere\textsuperscript{1)}. The electrocorticograms (ECoGs) recorded from the visual cortex were divided into 10 sec epochs, and the first 2 sec ECoGs of 200 consecutive 10 sec epochs were averaged with a CAT 400 B (Computer of Average Transients). The averaged ECoGs (AECoGs) were classified into the following seven waves by means of an EEG frequency analyzer (MAF-3, Nikkor): \( \delta_2 \) (1-2 c/sec), \( \delta_1 \) (2-4 c/sec), \( \theta \) (4-8 c/sec), \( \alpha \) (8-13 c/sec), \( \beta_1 \) (13-20 c/sec), \( \beta_2 \) (20-30 c/sec) and \( \beta_3 \) (30-60 c/sec). The amplitude of each wave was measured by hand. Only five (\( \delta_2, \delta_1, \theta, \alpha \) and \( \beta_1 \) waves were taken into consideration in the final data analysis.

RESULTS

The amplitude of all five waves, prior to X-irradiation

The amplitude of each of the five waves (\( \delta_2, \delta_1, \theta, \alpha \) and \( \beta_1 \) waves differed from animal to animal, and showed relatively large within animal variability across recording sessions (Table 1). The \( \delta_2, \delta_1 \) and \( \theta \) waves constituted approximately 30\% of the sum of the amplitudes of all five waves, and the \( \alpha \) and \( \beta_1 \) waves were very small (Fig. 1).

Effects of fractionated X-irradiation

1,500 R (animals Nos. 399 and 400)

The changes in the amplitude of all five waves during and after fractionated X-irradiation are shown in Fig. 2, A. The amplitude of each of all five waves gradually decreased with increasing doses during fractionated irradiation. The decreased value remained relatively constant throughout the observation period after the end of exposure. There was no difference among the changes in the amplitude of all five waves in the same animals.

300 R (animals Nos. 424 and 441)

The effects of fractionated X-irradiation on the amplitude of all five waves are

Table 1. The mean value and standard deviations (in \( \mu \)V) of the amplitude of the five waves (\( \delta_2, \delta_1, \theta, \alpha \) and \( \beta_1 \)) of the AECoGs before X-irradiation. SD: standard deviations.

<table>
<thead>
<tr>
<th>Animal No.</th>
<th>( \delta_2 ) Mean</th>
<th>SD</th>
<th>( \delta_1 ) Mean</th>
<th>SD</th>
<th>( \theta ) Mean</th>
<th>SD</th>
<th>( \alpha ) Mean</th>
<th>SD</th>
<th>( \beta_1 ) Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>399</td>
<td>101.9</td>
<td>82.6</td>
<td>145.2</td>
<td>32.4</td>
<td>104.1</td>
<td>30.2</td>
<td>34.2</td>
<td>11.6</td>
<td>16.2</td>
<td>4.7</td>
</tr>
<tr>
<td>400</td>
<td>119.7</td>
<td>53.2</td>
<td>142.5</td>
<td>43.3</td>
<td>106.5</td>
<td>32.3</td>
<td>28.8</td>
<td>9.0</td>
<td>14.8</td>
<td>2.6</td>
</tr>
<tr>
<td>424</td>
<td>61.8</td>
<td>20.6</td>
<td>63.0</td>
<td>13.9</td>
<td>59.1</td>
<td>10.8</td>
<td>16.8</td>
<td>4.9</td>
<td>12.5</td>
<td>2.6</td>
</tr>
<tr>
<td>441</td>
<td>123.6</td>
<td>59.7</td>
<td>111.3</td>
<td>44.7</td>
<td>87.0</td>
<td>9.8</td>
<td>20.5</td>
<td>3.6</td>
<td>12.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Fig. 1. A typical example of the AECoGs (lower) and frequency analysis (upper). Three consecutive AECoGs are pooled together for the analysis. Calibration: 100 μV (upper), 10 μV (lower) and 2 sec.

shown in Fig. 2, B. The amplitude of each of all five waves did not change in any definite direction through the observation period.

DISCUSSION

The results reported here indicate that the spontaneous electrical activity of the visual cortex is gradually depressed by repeated X-irradiation. In previous papers\textsuperscript{1,2} we have demonstrated that the amplitude of the late components of the averaged evoked potentials (AEPs) to photic stimulation gradually decreased during
Fig. 2. Changes in the amplitude of the five waves of the AECogs during (left) and after (right) fractionated X-irradiation. c: before fractionated X-irradiation. Arrows show X-irradiation. The value before fractionated X-irradiation is shown as 100%.
Fig. 2. (Continued)
fractionated irradiation. Hakansson et al.\textsuperscript{3} also reported that cerebral electrical activity in the slow frequency range changed during fractionated X-irradiation treatment following surgery for malignant cerebral tumours. In studies of a single irradiation of moderate X-ray doses, many authors\textsuperscript{4-7} reported that the EEG and the evoked potentials changed for some dozen days following exposure. From the above considerations, the finding in this study and previous reports\textsuperscript{1,2} may suggest that a successive dose is administered while the effects induced by a preceding X-ray dose continue.

The data reported here show that the spontaneous electrical activity of the visual cortex decreases after fractionated X-irradiation. Eldred and Trowbridge\textsuperscript{8} reported that no remarkable change in the EEG was noted in most monkeys examined from a few hours to several months after whole body exposure to 400–800 R, until just prior to death. They are of the opinion that the terminal alterations are secondary to the general breakdown of the body's homeostasis. Focal abnormalities in the EEG recording several months after irradiation with 1,500 R to the head may be related to the presence of widespread miliary scarring of the brain\textsuperscript{9}. Arnold et al.\textsuperscript{10} also reported that the monkey showed abnormal EEG activity eight months after administration of 375–1,500 R of 23 MeV X-rays to the head. Bailey et al.\textsuperscript{11} implanted \textsuperscript{182}Ta, yielding a dose of approximately 400–600 R in the cerebral cortex of monkeys for a 4-6 day exposure. EEG examinations were repeated every two to three months for three years. Three months after exposure, records were almost normal in appearance, but after long periods of time, the EEG tended to be faster than normal, with some spike and slow waves. Two animals showed epileptiform patterns after about two years. These changes are thought to reflect progressive delayed damage to the brain as a result of irradiation. The EEG in the monkey showed amplitude asymmetry and abnormal slow activity 20 to 47 weeks after irradiation with 3,500 rads to the right side of the head.\textsuperscript{12} These authors analyzed the brain electrical activity only qualitatively, by conventional inspection of the EEG tracings. The present study, using a computer, demonstrates quantitatively that the brain electrical activity is depressed by fractionated X-irradiation. In a study on mongrel dogs Kramer et al.\textsuperscript{13} also calculated average peak amplitudes and frequency ranges of the EEG divided into high voltage, low frequency and low voltage, high frequency. Spike-like activity and rhythm instability were observed in the EEG at two and one-half years after exposure to 1,000 R head X-irradiation. The changes corroborate the total clinical picture of late radiation encephalopathy.

In a previous paper\textsuperscript{1} we have reported that the AEPs gradually decreased after fractionated X-irradiation of 300 and 1,500 R. The amplitude of the AECOGs of the visual cortex was below control levels after fractionated irradiation of 1,500 R, and no specific changes were observed from the animals irradiated with 300 R. These results suggest that the AEPs are more radiosensitive activity than the AECOGs. Further arguments supporting this conclusion are: (1) an evoked poten-
tional is a response to a stimulus on a specific sensory pathway, while EEG is a spontaneous electrical activity from many nerve cells; (2) the AEPs can be obtained when EC0Gs are of low voltage and fast wave, whereas the AEC0Gs can be obtained from animals in all stages of sleep and wakefulness. Generally, the amplitude of evoked potentials is large and stable when the background EEG activity is of low voltage and fast wave\textsuperscript{14-16}.

ACKNOWLEDGEMENTS

We acknowledge the technical staff of National Institute of Radiological Sciences for their help. We also express our appreciation to Miss kuniko Aratake for her technical assistance and to Miss Keiko Yonekawa for her assistance in the preparation of the manuscript.

REFERENCES
