Effects of X-Irradiation on Evoked Potentials from Visual System in Rabbits**

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ABSTRACT

Effects of X-rays on visual system were electrophysiologically studied in rabbits which were subjected to 250 R or 500 R or head-only irradiation. Three types of the evoked potentials which were elicited in the visual cortex and in the lateral geniculate body by photic stimulation and in the visual cortex by electrical stimulation to the lateral geniculate body were recorded up to 10 days following irradiation. The amplitude and the duration of the evoked potential from the visual cortex by photic stimulation decreased and reached a minimum value 8 hours after irradiation. This was immediately followed by a gradual increase in amplitude and duration to levels close to the control on the first day, but the return to control was not complete, even at the end of 10 days. These reductions were more marked after irradiation of 500 R than that of 250 R. The changes of the two other potentials were very similar to that elicited in the visual cortex by photic stimulation. These results can be attributed to a depressing influence of X-rays on the whole visual system. This finding draws further attention to the fact that these potentials depend on events occurring in the reticular formation. Some implications of the effects of X-rays on the rabbit visual system are discussed.

INTRODUCTION

Recent investigations have indicated that the function of the central nervous

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System can be altered by whole body or head-only exposure to relatively moderate doses of X-rays, which cause no gross morphological damage. Monnier and Krupp\textsuperscript{10} observed desynchronization and some reduction in the voltage of spontaneous electrical activity in rabbit brain, together with spike discharges in the hippocampus, after an exposure of the head to X- or gamma-rays (400 R and 600 R). Gangloff and Haley\textsuperscript{11} reported that in cats the discharges of spike potential in the hippocampus increased and the reticular arousal threshold decreased following X-irradiation with 200 R or 400 R. Etienne and Posternak\textsuperscript{3} demonstrated transitory alterations of the early evoked response in cat visual cortex after gamma irradiation with 200 R to 1,200 R. Monnier and Hösli\textsuperscript{4} pointed out that in rabbits the latency of the various components of the early cortical response by photic stimulation decreased and the amplitude of the EEG increased slightly within a few hours after 400 R and 1,200 R of X-irradiation.

The slow component of the visual evoked potentials, as well as the EEG, has, served widely as a useful index of brain function\textsuperscript{5,6}. The authors previously reported that in rabbits the visual evoked potential decreased after X-irradiation of 1,000 R\textsuperscript{7}. Present investigation was designed to detect the effects of X-rays (250 R or 500 R) on the slow evoked potential recorded from the visual system of the rabbit.

**MATERIALS AND METHODS**

Twenty adult rabbits, weighing about 3.0 kg at the beginning of the experiments, were used. Animals were housed in individual cages except when electrical activity was recorded.

Rabbits, under Nembutal anesthesia, were held in a stereotaxic apparatus. The scalp was reflected, and two types of electrodes were stereotaxically implanted. Small ball-ended silver wire (0.5 mm in diameter) was gently applied to the cortical (sensory, motor and visual) surface. A bipolar electrode made with a stainless steel tube (0.6 mm in diameter) in which was placed an enamelled copper wire polished at the tips, was inserted to the lateral geniculate body. The reference electrode, made of a screw, was fixed in the bony septum between the frontal sinuses. The confirmed positions of these electrodes were confirmed according to the instructions of the atlas of Monnier and Gangloff\textsuperscript{10}. The leads of these electrodes were soldered to the pins of a miniature tube socket which was in turn fastened to the cranium with dental cement.

Recording was undertaken several days after the animals recovered from surgery. The animal was placed in a lucite box which was put in a dark, sound-proofed room. Spontaneous electrical activity and evoked potentials were recorded on an electroencephalograph (ME-40D, Nikkor), and displayed on a double beam oscilloscope (VC-6, Nikkor). Monopolar recording was employed in this experiment. A photic stimulator (MS-IPS, Nikkor) which triggered a flash of white light was employed to elicit specific visual potential. The lamp was placed 100 cm in front of the animal. The electrical stimulation of the lateral geniculate body was bi-
polarly effected by means of 0.2 msec duration and 5-20 volts as a rectangular pulse through an isolation transformer (MSE-3, Nikkor). These stimulations were presented at a frequency of one cycle per second.

X-rays were generated at 250 kVp and 15 mA. The beam was filtered through 0.5 mm copper and 1.0 mm aluminium, and the target-to-skin distance was 40 cm. Doses of 250 R (L-group) and 500 R (M-group) were delivered at the rate of 100 R/min. The size of the beam was 8×8 cm. The animals were laterally irradiated over the head.

RESULTS

Spontaneous electrical activity recorded from both the visual cortex (VC) and the lateral geniculate body (GL) showed either a sleep pattern (high amplitude and slow wave) or an arousal pattern (low amplitude and fast wave). Each pattern occurred synchronously in these two structures (Fig. 1). Although abnormalities in the electrical activity were not observed after X-irradiation, the sleep pattern increased slightly.

Three types of the evoked potentials which were elicited in VC and GL by photic stimulation to both eyes, and in VC by electrical stimulation to GL, were recorded from several days before irradiation until 10 days after irradiation. These evoked potentials usually consisted of a slow wave with about 20 msec latency. The amplitude and the duration of these waves varied from one animal to other and also fluctuated in the same animal. In this experiment the evoked potentials were recorded at the times when the spontaneous electrical activity showed the

![Graph of Spontaneous Electrical Activity](image)

**Fig. 1.** Spontaneous electrical activity of rabbit brain.
Upper: sleep pattern (high amplitude and slow wave)
Lower: arousal pattern (low amplitude and fast wave)
VC: the visual cortex.
GL: the lateral geniculate body.
arousal pattern, because the fluctuation in this pattern was less than in the sleep pattern. The peak amplitude and the duration of the slow wave were analysed. The amplitude of normal animals was about 350 μV and the duration was about 300 msec.

The observed changes are graphically summarized in Figs. 2 and 3. Thirty evoked potentials were averaged in each point.

After X-irradiation, the amplitude the evoked potential from VC by photic stimulation decreased, and reached a minimum value 8 hours after irradiation. A gradual increase followed for both the L- and M-groups. The minimum value was smaller in the M-group than in the L-group. In the L-group the amplitude tended to return toward control level on the 1st day, while in the M-group the increase was very slow during the first 5 days. For both groups, the return to control level was not complete even by the 10th day after irradiation. The duration of the potential in both groups decreased after irradiation, also reaching a minimum value 8 hours after irradiation. It increased slightly on the next day, and then showed a constant value until the 10th day after irradiation. The amplitude changed more obviously than the duration.

Fig. 2. a) An example of the evoked potential recorded from the visual cortex by photic stimulation in a control animal. Upper: five sweep traces superimposed. Lower: single trace. Vertical and horizontal lines show the amplitude and the duration, respectively.

b) An example of the evoked potential recorded from the lateral geniculate body by photic stimulation.

c) An example of the evoked potential recorded from the visual cortex by electrical stimulation to the lateral geniculate body.
Fig. 3. a) Changes of the evoked potential recorded from the visual cortex by photic stimulation after X-irradiation. The plotted values represent the means from the data of 6 animals in each group. C: control.
b) Changes of the evoked potential recorded from the lateral geniculate body by photic stimulation after X-irradiation. The plotted values represent the means from the data of 6 animals in each group. C: control.
c) Changes of the evoked potential recorded from the visual cortex by electrical stimulation to the lateral geniculate body after X-irradiation. The plotted values represent the means from the data of 4 and 5 animals in each group. C: control.

The post irradiation changes of the amplitude and the duration of the evoked potentials from GL by photic stimulation and from VC by electrical stimulation to GL were very similar to the changes elicited in the potential from VC by photic stimulation. However, the evoked potential to electrical stimulation changed a little less than the two other evoked potentials.

Although the amplitude of these evoked potentials decreased more distinctly in the M-group than in the L-group, there was no observed difference between groups as far as changes of duration were concerned.

DISCUSSION

The results reported here indicate that the evoked potentials recorded from the visual system in waking rabbits decreased after 250 R or 500 R of head X-irradiation. Similar results were obtained with irradiation of 1,000 R². Etienne and Posternak³) stated that transitory alterations of the early electrical response of cat visual cortex by electrical stimulation to the optic radiation, after irradiation with 200 R to 1,200 R, were due to the drowsiness of the animal rather than to a direct action of the irradiation on the cortex. According to Monnier and Hölsi⁴), a decrease in latency and in culmination time of the early electrical response of rabbit visual system to photic stimulation, after irradiation with 400 R and 1,200 R, can be attributed to an initial activating influence of ionizing radiation on the whole
visual system. Hrěbiček et al.\textsuperscript{9} reported that in rats a slight change of the evoked response taken from the visual cortex by light stimulation after X-irradiation (300 R or 450 R) was due to a decreased activity of the nervous elements of deeper cortical layers, especially the 4th layer. The third and the fourth surface positive waves of the visual cortical response were altered markedly from 2 days to 2 years after irradiation of massive doses of protons or deuterons\textsuperscript{10). The results presented here differed somewhat from those described above. The main difference is probably due to the fact that in this experiment the slow response was analysed, whereas the above workers studied the early response.

In the present results, the authors showed that the evoked potential decreased in amplitude and in duration after X-irradiation. Ciganek\textsuperscript{11) divided the EEG response to light stimulation in man into two components (primary and secondary responses), and assumed that the former had the character of a potential produced by a specific pathway and the latter by non-specific ones. Fuster and Docter\textsuperscript{12) studied the amplitude fluctuations of photically evoked potentials in rabbit visual system as reticular activity was alternately lowered by Nembutal and increased by tegmental stimulation of the mesencephalon, and concluded that there was a close and direct relationship between the level of reticular activity and the amplitude of secondary response of the visual cortex. From the fact that the evoked potentials recorded from the visual system were lost at 24°C esophageal or buccal temperature in nonhibernators (cat and guinea pig), but persisted at 17°C in hibernators (prairie dog and ground squirrel), Massopust and Wolin\textsuperscript{13) concluded that the resistance of anterior reticular formation to cold in the hibernator was stronger than that in the nonhibernator. It is considered that the slow wave observed in the present experiment is identical with secondary response\textsuperscript{11,12) and the evoked potential\textsuperscript{13).}

On the basis of evidence presented thus far, it seems that the reduction of the evoked potential is attributed to the depression of the ascending reticular activating system in brain stem affected by X-rays.

Since the radiation field included the retina in the present experiment, it cannot be denied that the retina, a radiosensitive tissue, was affected by X-rays. However, it is evident that the rest of the visual system is also affected for the following reasons: (1) the reduction of the evoked potential from VC by electrical stimulation to GL was observed after irradiation, (2) the authors found that in human patients the visual evoked potential by photic stimulation decreased after localized irradiation to the hypophysis (in press).

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REFERENCES

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