ELECTROPHYSIOLOGICAL INVESTIGATION OF CHANGES IN CORTICAL ACTIVITY OF RABBITS AFTER WHOLE-BODY EXPOSURE TO IONIZING RADIATION

V. M. Anan'ev, A. M. Kogan, and V. A. Nazarov

UDC 612.825.014.482.014.423

The dynamics of cortical electrical activity at 20 points was studied in rabbits after whole-body exposure to ionizing radiation in doses of 1000 and 1500 R. The results showed that global bioelectrical activity is a less sensitive index than indices taking account of the duration of the potentials. Changes in bioelectrical activity after irradiation differ in different parts of the cortex.

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Following whole-body x-ray irradiation of rabbits in doses of 800-1000 R, the cortical electrical activity undergoes considerable changes which occur in definite phases [2]. However, the experiments on which these conclusions are based were carried out with single leads.

The object of the present investigation was to study the dynamics of cortical electrical activity on rabbits at 20 points simultaneously after whole-body irradiation in lethal doses (1000 and 1500 R). By recording the potentials at many different points simultaneously it was possible to study whether differences exist in the character of electrical activity in different zones of the cortex.

EXPERIMENTAL METHOD

Experiments were carried out on 4 rabbits weighing 2.5-3 kg. The rabbits were scalped, and 2-3 days later 20 stainless steel electrodes were implanted into the skull and covered with acrylic glue. The arrangement of the electrodes is shown in Fig. 1, 1. Monopolar leads were used. The reference electrode was located in the frontal bone.

The potentials were amplified by means of an electroencephaloscope with commutation frequency of 50/sec. The potentials were recorded from 20 points simultaneously by means of a multiple analyzer on magnetic tape in the form of a successive 5-discharge code impulse [1, 3]. Each individual recording lasted 20 sec. The results of preliminary amplitude analysis recorded on magnetic tape were introduced by means of a marker selector and special input device into the memory of Ural-2 electronic computer and analyzed mathematically in accordance with a complex program [3].

The animals were investigated as follows. For the first few days the background electrical activity was recorded. The rabbits were then exposed to whole-body irradiation with γ-rays (Co^{60}). The dose rate was 164 R/min. Two rabbits were irradiated in a dose of 1000 R and two rabbits in a dose of 1500 R. The first recording of bioelectrical activity was made 15 min and the next 30 min after irradiation, and subsequently recordings were made every hour for 6-8 h and then every day until the animal's death.

EXPERIMENTAL RESULTS

To analyze the results obtained the background values of certain indices were compared with their later values. When this comparison was made using the integral activity S (the area bounded by the electroencephalogram) as index the following dynamics of radiation damage was obtained for the group of rabbits irradiated in a dose of 1000 R. During the first hour after irradiation activity remained within the background limits. After 2 h the integral activity began to increase and reached a maximum 4 h after irradiation. After 5 h the activity again fell to the background level. Next day activity of one of these rabbits again

Institute of Biophysics, Ministry of Health of the USSR, Moscow (Presented by Active Member of the Academy of Medical Sciences of the USSR P. D. Gorizontov). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 65, No. 6, pp. [illegible], June, 1968. Original article submitted January 23, 1967.

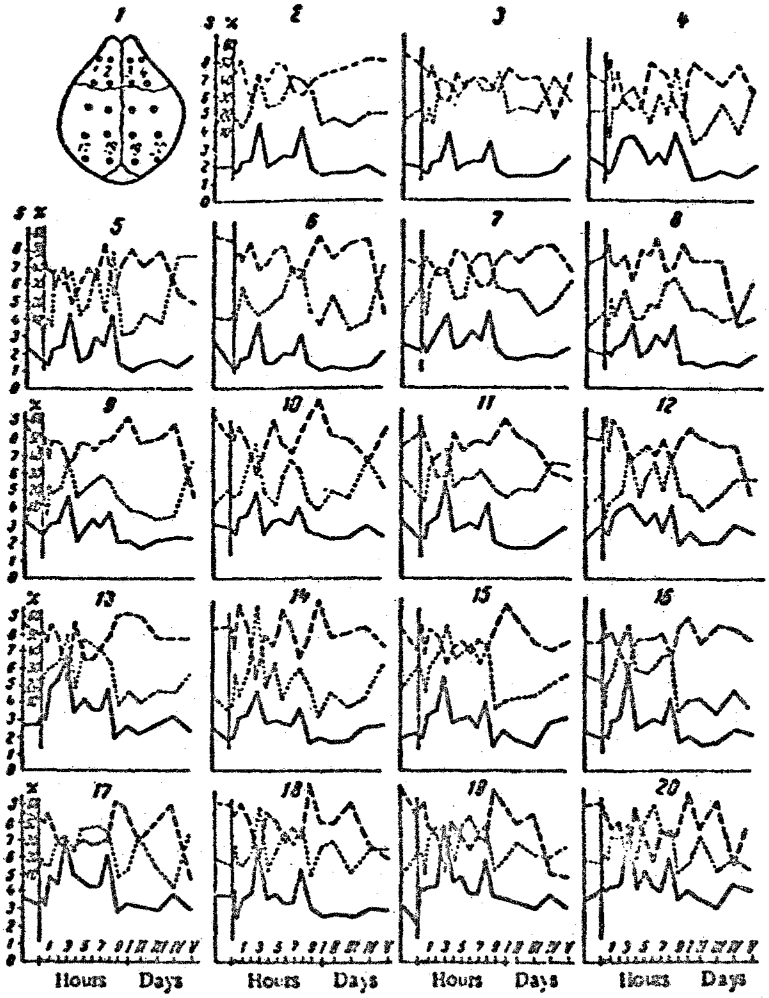

Fig. 1. Dynamics of cortical electrical activity of a rabbit recorded at 19 points after whole-body irradiation with γ-rays in a dose of 1500 R. Rabbit No. 77: 1) arrangement of recording electrodes. Continuous line represents integral electrical activity S; dotted line shows index S_2 (frequency 1-3 cps); broken line index S_3 (frequency 3-8 cps). Vertical line denotes moment of irradiation. For clarity, curves S_2 and S_3 are elevated three divisions above the abscissa.

rose slightly, falling again on the 3rd day, while in another rabbit activity was greater on the 3rd day and then fell to a level slightly below the background. On the 6th day the activity of both rabbits again began to increase, but on the 7th day after irradiation the animals died.

In the group of rabbits irradiated in a dose of 1500 R changes in integral activity were observed sooner. The increase in activity began toward the end of the first hour after irradiation, reaching a maximum 3 h after irradiation. In rabbit No. 77 (Fig. 1) 8 h after irradiation the integral activity again rose significantly, thereafter falling to slightly below the background level. Subsequently fluctuations in the integral electrical activity were observed within the limits of the initial background level. In a second rabbit of this group, the integral activity rose again two days after irradiation, after which it fell steadily until the animal died. Both rabbits died on the 6th day after irradiation.

When analyzing the frequency spectrum of the potentials we used three types of distribution functions. The first function reflected the number of halfwaves of a particular duration during the time of a given recording as a percentage of the total number of halfwaves in the recording [$F_1(T) = \frac{n_T}{N_{halfwaves}}$].

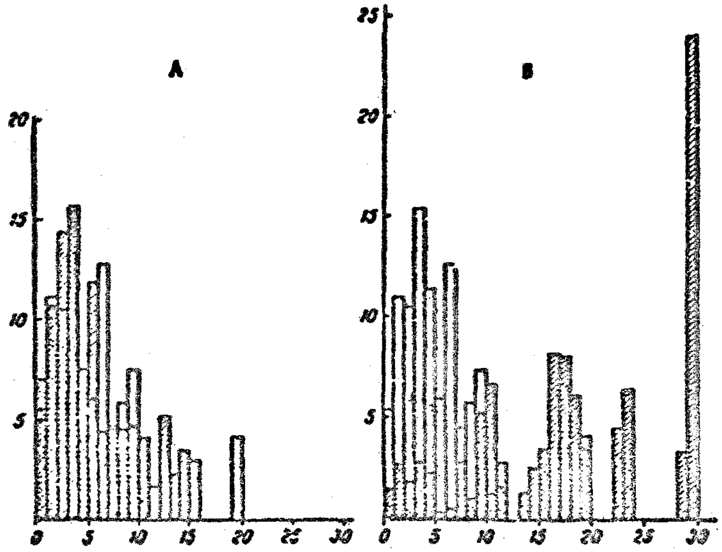

Fig. 2. Distribution $S_T = f\,(T)$. Rabbit No. 81 (point No. 1). A) 15 min; B) 6 days after irradiation (last trace before animal's death). Abscissa, commutation intervals; ordinate, $S_T/S_{halfwaves}$ (in percent). Diagrams obtained by superposing background values after irradiation. Positive and negative halfwaves of equal duration summated. Unshaded columns indicate that background exceeds irradiation value; columns with single shading, irradiation exceeds background. Areas of coincidence are shown by double shading.

The discrete values of halfwave durations were taken every commutation interval (0.02 sec) from 0 to 30 for the positive and negative halfwaves.

The second function showed the time occupied by halfwaves of a given duration expressed in relation to the total time of the recordings $[f_2(T) = t_T/t_{exp}]$. It must be remembered that this distribution gives indices analogous to those used in clinical practice. The third function gave the value of the integral area for halfwaves of a given duration in relation to the total area of the electroencephalogram $[f_3(T) = \frac{S_T}{S_{halfwaves}}]$ (Fig. 2).

To facilitate analysis of the enormous numerical material, we subdivided the frequency spectrum as a whole into four subranges: the first below 1 cps (from 26 to 30 commutation intervals), hardly detectable by our apparatus; the second from 1 to 3 cps (9-25 commutation intervals); the third from 3 to 8 cps (4-8 intervals); and the fourth over 8 cps (1-3 intervals). We used the term "indices" to describe the numerical values of the parameters n_{1-4}, t_{1-4}, and S_{1-4} in these subranges.

Analysis of the material relative to duration of halfwaves (n_T) showed that the character of the dynamics of the indices was mainly oscillatory; n_2 slightly exceeded the background line, and deviations of n_3 and n_4 took place mainly near this line. At the time of death of the animal n_2 was increased but n_4 decreased. The distribution of t_T also shows the oscillatory character of the dynamics of these indices. The value of the index t_T was mainly above the background line, t_3 was slightly below it, while t_4 fluctuated around the background line with a tendency to move below it. At the time of the animal's death t_2 was obviously increased while t_3 and t_4 were considerably decreased. Examination of the distribution of S_T shows that the index S_2 was definitely above background line, S_3 was below this line, and S_4 mainly fluctuated within the background limits. At the time of the rabbit's death S_2 had increased still further while S_3 [illegible] creased (Fig. 1).

The following picture was obtained by plotting a graph of the complete distribution of S_T [illegible] indices which were [illegible]. In the first recording (15 min after irradiation) a slight [illegible] in the relative number of [illegible] and a decrease in the number of slow waves was obtained (Fig. 2, A), [illegible] ponding to a stage of excitation. The picture changed sharply 3 h (with a dose of 1500 R) or 4 h [illegible] after irradiation: the percentage of fast waves fell considerably and that of the slow waves rose rapidly (stage of inhibition). After a few days the relative proportion of fast waves again rose slightly (stage of relative normalization), but before the animal's death the percentage of fast waves became negligible and strong slow waves predominated (Fig. 2, B).

The results thus showed that the study of changes in cortical electrical activity in response to irradiation using integral activity as the criterion is insufficient and must be supplemented by the study of criteria taking into account the duration of the potentials. Using integral activity, for instance, changes could be found only toward the end of the first hour after irradiation (dose 1500 R; Fig. 1) or 2 h after irradiation (dose 1000 R). Yet on the graph of distribution of S_2 (Fig. 2) these changes could be detected in the first trace (taken 15 min after irradiation). The graph of integral activity reveals a considerable increase 3-4 h after irradiation (depending on the dose). At first glance this increase in activity may be taken as a sign of increased cortical activity. However, analysis of our other criteria shows that in fact this increase in integral activity was due entirely to an increase in the relative proportion of slow waves, and, consequently, it is a sign of increasing inhibition (Fig. 1).

We compared the activity in the last background trace (i. e., immediately before irradiation) with the activity at the moment of deepest depression. This comparison was made for each of the 20 recording points. The greatest difference between these values of activity was found in the right occipital cortex and the smallest in the parietal cortex, on the left side in three rabbits and on the right in one. A detailed study of the comparative sensitivity of topographically different cortical areas will be the subject of our next investigation.

LITERATURE CITED

1. V. M. Anan'ev, Byull. Éksperim. Biol. i Med., No. 1, 91 (1966).
2. M. N. Livanov, Some Problems in the Action of Ionizing Radiation on the Nervous System [in Russian], Moscow (1962).
3. V. A. Nazarov, Byull. Éksperim. Biol. i Med., No. 1, 95 (1966).