RESISTANCE OF THE COMPENSATORY MECHANISMS OF THE NERVOUS SYSTEM TO ACUTE RADIATION SICKNESS (USING UNILATERAL LABYRINTHECTOMY AS MODEL)

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The study of the compensatory powers of the nervous system during the action of ionizing radiation is incomplete. The nervous mechanisms of compensation are known to be highly resistant [6]. It has been shown experimentally that the tonic reflexes of the brain stem are increased after whole-body irradiation in doses of 800-1000 R [10]. However, no reference could be found to the study of the state of the compensatory nervous mechanisms of disturbed functions, with qualitative and quantitative assessment of the reactions in the course of development of acute radiation sickness.

Accordingly, at Professor Yu. G. Grigor'ev's suggestion, the present investigation was carried out to examine the resistance of the compensatory mechanisms of the nervous system to acute radiation sickness.

EXPERIMENTAL METHOD

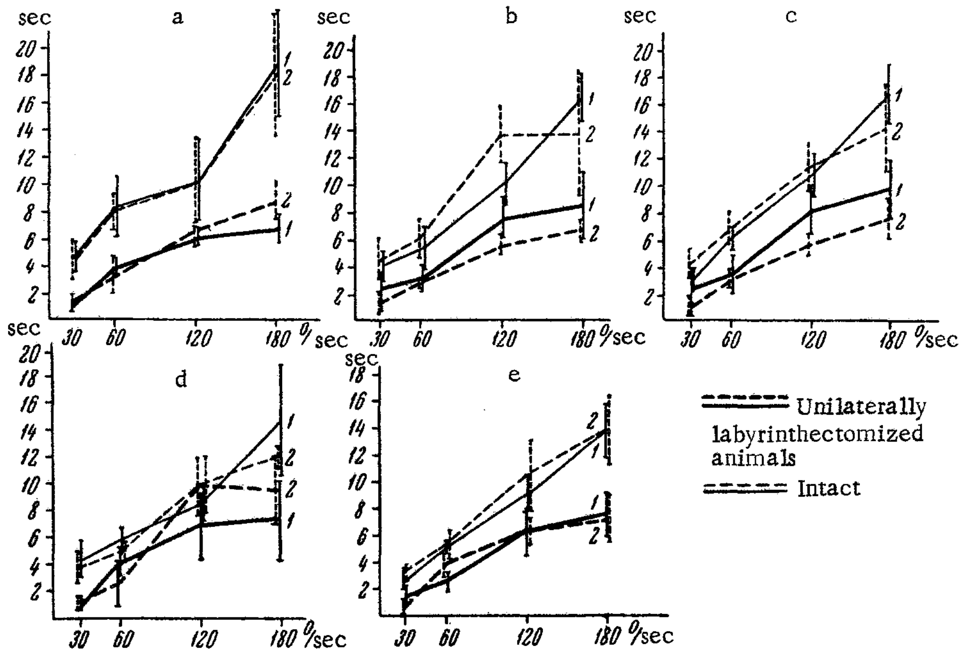
The model chosen to characterize the state of the compensatory mechanisms of disturbed functions was unilateral labyrinthectomy, highly developed by É. A. Asratyan's school. The group of vestibular nuclei present in the medulla lies on the pathway of several labyrinthine reflexes. One such reflex is the nystagmic movement of the eyes in response to stimulation of the semicircular canals of the labyrinth. By recording the reactions of postrotational nystagmus in an animal with one labyrinth, the state of the compensatory processes developing after labyrinthectomy can be judged.

Experiments were carried out on 23 male chinchilla rabbits weighing 2.5-3.2 kg, of which 12 were experimental and 11 control. The left labyrinth was destroyed in the experimental animals. The approach to the fenestra vestibuli was made by the technique described by N. I. Arlashchenko, Yu. G. Grigor'ev, and A. B. Malinin [2]. Next, under visual control, the membranous labyrinth was extracted piecemeal. The completeness of extirpation of the labyrinth was verified histologically.

The animals were examined on a special rotating apparatus [5]. Rotation began with subthreshold levels of acceleration, after which a series of stimuli of increasing magnitude was applied—30, 60, 120, and 180°/sec, the animals being rotated in both directions alternately. The nystagmic reactions which developed on stopping were transmitted by means of needle electrodes and a special device to a 16-channel electroencephalograph (Kaisers Laboratorium). Between 4.5 and 6 months later, when the disturbances caused by the unilateral labyrinthectomy had subsided or disappeared completely, the animals were exposed to whole-body irradiation (dose 800 R, dose rate 200 R/min).

After irradiation the rabbits were tested on the rotating apparatus at different stages of radiation sickness — 4-5 h after irradiation, and then on the 3rd, 5th, and 8th days. Besides the recording of the nystagmic reactions, a full blood analysis was made, and the animal was weighed so that the course of the radiation sickness could be assessed clinically.

No operation was performed on the control animals, but they were tested and irradiated in the same conditions as the experimental animals.



Curves of reactivity of the vestibular analyzer in rabbits after unilateral removal of the labyrinth and in intact animals at various times after whole-body γ-ray irradiation in a dose of 800 R. 1) Anticlockwise rotation; 2) clockwise rotation. The vertical lines denote the magnitude of one mean error (m).

A statistical analysis of the experimental results was made by Student's method.

EXPERIMENTAL RESULTS AND DISCUSSION

Immediately after the unilateral destruction of the labyrinth the equilibrium of the postrotational nystagmus after turning to the left and right disappeared. After 4.5-6 months this equilibrium was restored. The curves of reactivity of the vestibular analyzer of the experimental (labyrinthectomized) and control animals are shown in the figure a. The curves reflecting the reactions of the labyrinthectomized and control rabbits to rotation to the left and right are almost parallel at all points; the difference is not statistically significant. The duration of the nystagmic reaction of the experimental animals fell by approximately half by comparison with the duration of the reaction of the controls.

The experiments with the control rabbits showed that statistically significant differences were not present at all stages of radiation sickness and at all points of the curves of reaction to turning to the left and right.

The course of the curves in the experimental animals 4-5 h after irradiation was not significantly altered (see figure b). No significant differences were found between the results of the reactions to clockwise and anticlockwise rotation. The blood analysis showed the usual hematological picture of the first day of radiation sickness. On the 3rd day after irradiation (see figure c) the course of the curves was unchanged. The lymphopoiesis was slightly depressed and the animals showed a very slight loss of weight.

On the 5th day after irradiation the relationship between the curves of reactivity during clockwise and anticlockwise rotation remained as before. The mean errors of the arithmetical means of the clockwise rotation curve were small (see figure d). The hematological picture was that usually observed on the 5th day of radiation sickness.

On the 8th day after irradiation no significant differences were found at any point on the curve (see figure e). The erythrocyte count and the concentration of hemoglobin in % were lowered; the depression of lymphopoiesis had progressed further and the loss of weight by the animals had continued.

After unilateral destruction of the labyrinth in animals a series of reflexes arises (spontaneous nystagmus, deviation of the eyes, rotation of the head, and so on), diminishing or disappearing in time, and in the opinion of some investigators these are the result of central compensatory processes [11, 13, 16]. It has been shown that the equilibrium normally present between the vestibular nuclei on account of the spontaneous activity of the analyzer on both sides is disturbed after labyrinthectomy; the activity of the nuclei on the side of the operation disappears at once [15]. This is shown by the fact that the postrotational nystagmus on the side of the operation after unilateral labyrinthectomy is much weaker than on the healthy side [17]. However, the activity of the nuclei on the side of the operation is evidently gradually restored [18]. As Spiegel and Demetriades [18] showed, after destruction of the vestibular nuclei on the side of the operation the function of the lost labyrinth was not compensated.

In man, some time after the loss of labyrinthine function on one side, nystagmic reactions of equal intensity on both sides develop in the rotation and caloric tests [12]. This demonstrates compensation of the lost function.

The facts described above show that compensation takes place on account of central mechanisms and not of the remaining labyrinth. For instance, after preliminary removal of the labyrinths from animals, destruction of the nuclei on one side caused the development of a nystagmus directed towards the side of the remaining nuclei [19].

Hence, a short time after unilateral loss of the labyrinth, the lost function is restored on account of central compensatory mechanisms (in the present experiments after 4.5-6 months). When assessing the compensatory processes the relative role of the phylogenetically old and young structures of the nervous system must be remembered [9]. V. M. Bekhterev [4] showed that destruction of the cerebral hemispheres diminishes the vestibular symptoms of delabyrinthized dogs. In E. A. Asratyan's investigations [3] extirpation of the cerebral hemispheres caused decompensation of labyrinthine lesions in these animals. After unilateral extirpation of the motor cortex, E. Sh. Airapet'yants and V.A. Kislyakov [1] observed a partial disappearance of the statokinetic reflexes developing in the process of compensation after labyrinthectomy.

The compensation of labyrinthine disturbances is thus not confined to the role of the brain stem. Consequently, when ionizing radiation acts on the living organism it is essential to take into account both the reactions of the individual nervous structures and the reactions of the central nervous system as a whole.

During irradiation changes of a phased character take place in the functional state of the cerebral cortex, and the centers of the medulla, the mesencephalon, and the diencephalon are characterized by increased excitability and conductivity [7, 10].

Analysis of the experimental results in the light of the facts described above shows that neither during the 1st day after irradiation, when the structures of the brain stem are in a state of increased excitability, but the cerebral cortex is in an inhibited state, nor in the period of a relative return to normal (3rd and 5th days) activity of the cortex and brain-stem centers, nor at the height of radiation sickness (8th day) when the processes are unstable in all parts of the nervous system, was there any disturbance of the previously formed compensatory mechanisms.

This suggests that the medulla, which plays the dominant role in the compensation of the labyrinthine disturbances (in this particular case), is highly resistant to irradiation. However, this does not exclude the resistance of the higher levels of the central nervous system to irradiation.

The results of control experiments demonstrate the progressive lowering of the reactivity of the vestibular analyzer, with a maximal fall before death of the animals. These results agree with the observations of A. V. Sevan'kaev [8]. The fact that no such progressive fall in the reactivity of the vestibular analyzer took place in the animals with one labyrinth after irradiation, as it did in the animals with two labyrinths, is of particular interest and calls for special study.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.