METABOLISM OF CATECHOLAMINES IN A SYMPATHETIC GANGLION DURING STIMULATION OF THE PREGANGLIONIC FIBERS OF IRRADIATED ANIMALS

L. D. Klimovskaya
and A. F. Maslova (Moscow)

UDC 617-001.28-092.9-07:616.839.19-008.944.53-074

When the functional state of the nervous system is disturbed by the action of ionizing radiation, factors modifying the conditions of the conduction of excitation in synaptic structures are of considerable importance [1, 2, 3, etc.]. The authors have previously investigated the course of processes associated with acetylcholine metabolism during the transmission of impulses in the sympathetic ganglia of irradiated rabbits [2].

The object of the present investigation was to study the reaction to irradiation of the adrenergic structures of the sympathetic ganglion. Determinations were made of the content of noradrenalin (NAD), adrenalin (AD), and oxidation products of adrenalin (OP) in the tissue of the superior cervical sympathetic ganglion before and after stimulation of the preganglionic fibers of the control and irradiated animals.

EXPERIMENTAL METHOD

Experiments were carried out on 36 rabbits. The conditions of these experiments were similar to those previously described [2]. The polarographic method was used for the quantitative estimations of NAD, AD, and OP.

The control series consisted of 22 rabbits.

EXPERIMENTAL RESULTS

The mean total content of NAD in 29 ganglia at rest was 1.25 ± 0.16 μg/g. In 10 of these ganglia the free and bound fractions of NAD were estimated separately in addition to the AD and OP. It was found that about 50% of the estimated NAD was bound with protein. The total contents of AD and OP were 0.27 ± 0.08 and 0.18 ± 0.07 μg/g respectively. In these circumstances the greater part of the AD (85%) was bound with protein, compared with 50% of the OP. Stimulation of the preganglionic fibers for 2 min led to a decrease in the content of catecholamines in the ganglion by 50-70% compared with their level at rest (Fig. 1). The physiological effect of stimulation was assessed from the development of a pupillary reaction. Throughout the period of stimulation a distinct and steady dilation of the pupil persisted. The fall in the content of catecholamines may evidently be regarded as one of the phases of activation of the adrenergic substrate, for stimulation of shorter duration (20-30 sec) increased the amount of catecholamines in the ganglion, but at the 2nd minute of stimulation a distinct accumulation of these substances was found in the fluid of the anterior chamber of the eye.

Between 1.5 and 24 h after a single whole-body exposure of 14 rabbits to γ-radiation in a dose of 400 R, changes took place in the content of catecholamines in the superior cervical sympathetic ganglion. For example, during this period the NAD content in 16 ganglia, not subjected to stimulation, had a mean value of 2.67 ± 0.57 μg/g, i.e., a statistically significant increase was observed in its absolute content by comparison with the control. The dynamics of the changes in the AD and OP contents were different. From 1.5 to 24 h after irradiation the AD content fell slightly on account of a decrease in the bound fraction to 0.09 ± 0.01 μg/g compared with 0.23 ± 0.08 μg/g in the control (Fig. 2). The total OP content at these times remained unchanged, but the proportion of the bound fractions fell to 22% (compared with 50% in the control).

(Presented by Active Member of the Academy of Medical Sciences of the USSR, A. V. Lebedinskii [deceased]). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 7, pp. 38-41, July, 1966. Original article submitted October 10, 1964.

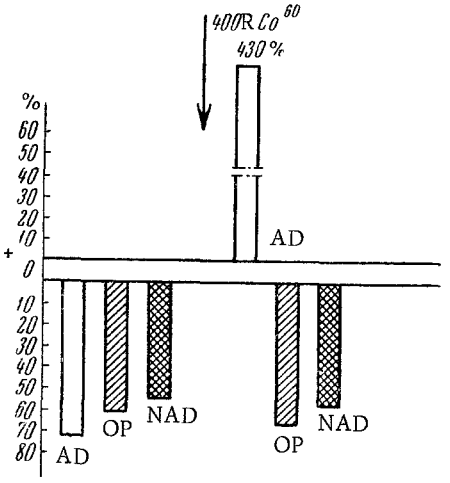

Fig. 1. Changes in content of catecholamines (in % of initial level) in the sympathetic ganglion during stimulation of the preganglionic fibers in rabbits. On the left—control; on the right—1-24 h after irradiation.

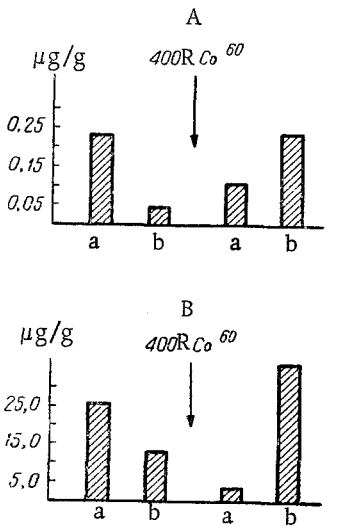

Fig. 2. Effect of stimulation of the sympathetic pathways and of irradiation on the content of bound adrenalin in the sympathetic ganglion (A) and adrenal of a rabbit (B). Here and in Fig. 3: a) before procedure: b) after procedure.

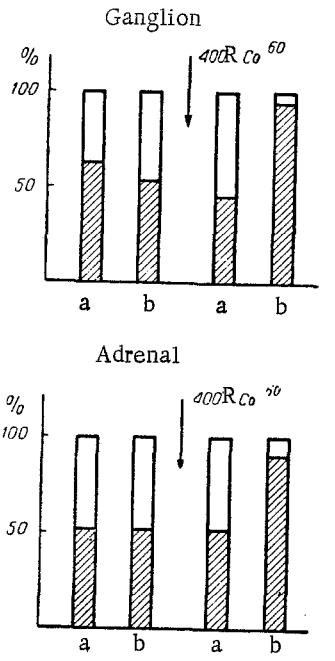

Fig. 3. Relative proportion (in %) of content of adrenalin and its oxidized form during stimulation of the sympathetic pathways in rabbits. Shaded part of column—AD; unshaded part—OP.

Stimulation of the preganglionic fibers in the irradiated animals caused the same changes in the NAD content as in the control (see Fig. 1). The AD content, however, unlike in normal conditions, did not fall towards the 2nd minute of tetanization, but rose sharply.

Analysis of the disturbances discovered was difficult because of the complexity of the problem of the role of catecholamines in the regulation of the functions of the body and the lack of unanimity regarding the relationship between NAD and AD [10, 11, 16]. The varied pattern of the changes in the contents of NAD and AD after irradiation was evidently due to the fact that their physiological role and the main sources of their formation in the ganglion were different. Possible sources of catecholamines are the bodies of the nerve cells, the chromaffin tissue, and the adrenergic nerve endings [12-15]. Since the greater part of the catecholamines in the ganglion consists of NAD [17], and in the adrenals — of AD [9, 18], it can be concluded that the main source of formation of NAD in the ganglion is nerve tissue. In this case the accumulation of NAD after irradiation may be regarded as the result of an increase in the mediator activity of the second neuron. Hence, during the action of ionizing radiation, different sections of the sympathetic nervous system are involved in the general reaction to an extreme factor [4].

The uniform character of the disturbances of AD metabolism in the sympathetic ganglion and the adrenal was noteworthy. One of the authors previously studied the effects of hypothalamic influences on the adrenals in irradiated rabbits. The results of these investigations are given for comparison in Figs. 2 and 3.

Analysis of the material presented in Fig. 2 shows that the changes in the AD content characterize the general reaction of chromaffin tissue. Its appearance in the first 24 h after irradiation took the form of a decrease in the absolute content of bound AD, both in the ganglion and in the adrenal. The picture described was evidently typical of activation of the chromaffin tissue, for it may be observed during stimulation of the sympathetic pathways running to these structures, and it is most probably due to an increase in the output of AD into the blood [5, 8]. Stimulation of the preganglionic fibers of the irradiated animals caused such a marked increase in AD formation that it accumulated in the ganglion. A similar picture was observed after irradiation in the adrenal also, during stimulation of the hypothalamic region (see Fig. 2). Incompletely oxidized forms of AD accumulated (see Fig. 3). Since

the ratio between AD and OP was a fairly stable quantity, the dissociation observed during stimulation of the sympathetic pathways of the irradiated animals between the rate of formation of AD and the rate of its oxidation by the quinoid route may be regarded as an expression of the disturbance of the physiological equilibrium.

It should also be borne in mind that the increased accumulation of AD during stimulation of the preganglionic fibers may lead to a change in the energy balance. This is perhaps one of the causes of the previously [2] observed disturbance of acetylcholine synthesis in the process of ganglionic transmission in irradiated animals.

SUMMARY

The object of study was determination of free and associated fractions of noradrenaline, adrenaline and oxidation products of adrenalin in the tissue of the superior sympathetic ganglion in rabbits. It was found that after a total gamma γ-radiation in a dose of 400 R there was an increase in the amount of noradrenaline and a decrease in adrenaline. Stimulation of the preganglionic fibers in control experiments for 2 min led to a decrease in the content of all catecholamines. At the same time, the amount of the nonoxidated fraction of noradrenaline markedly increased in irradiated animals.

LITERATURE CITED

1. L. D. Klimovskaya, Byull. Éksp. Biol., No. 1 (1962), p. 22.
2. L. D. Klimovskaya and A. F. Maslova, Byull. Éksp. Biol., No. 6 (1966), p. 50.
3. A. V. Lebedinskii, Yu. G. Grigor'ev, and G. G. Demirchoglyan, Proceedings of the 2nd International Conference on the Peaceful Use of Atomic Energy, Lectures by Soviet Scientists, Radiobiology and Radiation Medicine [in Russian], Vol. 5, Moscow (1959), p. 5.
4. A. V. Lebedinskii and Z. N. Nakhil'nitskaya, Effect of Ionizing Radiations on the Nervous System [in Russian], Moscow (1960).
5. A. F. Maslova, Med. Radiol., No. 12 (1959), p. 36.
6. A. F. Maslova, Biokhimiya, No. 2 (1959), p. 181.
7. B. B. Moroz, S. P. Grozdov, and E. N. Petrovnina, Radiobiologiya, No. 4 (1962), p. 543.
8. V. O. Osinskaya, Biokhimiya, No. 3 (1957), p. 537.
9. M. E. Raiskina, Biochemistry of the Nervous Regulation of the Heart [in Russian], Moscow (1962).
10. A. M. Utevskii, In: The Mechanism of Action of Hormones [in Russian], Kiev (1959), p. 27.
11. D. A. Kharkevich, Ganglionic Substances [in Russian], Moscow (1962).
12. V. S. Sheveleva, The Interneuronal Transmission of Excitation in the Sympathetic Ganglia [in Russian], Leningrad (1961).
13. E. Bülbring, J. Physiol., Vol. 103, London (1944), p. 55.
14. R. M. Eccley and B. Libet, Ibid., Vol. 157 (1961), p. 484.
15. U. S. Euler, Noradrenaline, Chemistry, Physiology, Pharmacology and Clinical Aspects, Springfield (1956).
16. E. Musholl and M. Vogt, J. Physiol., Vol. 141, London (1958), p. 132.
17. C. E. Rapella, Acta Physiol. Lat.-Amer., Vol. 6 (1956), p. 1.
