MORPHOLOGICAL RESPONSE OF THE HYPOTHALAMO-HYPOPHYSEAL NEUROSECRETORY SYSTEM TO SUGAR LOADING IN RATS DURING ONTOGENESIS

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The response of the hypothalamo-hypophyseal neurosecretory system of adult rats to sugar loading consists of a phase shift of the secretory cycle toward greater than normal accumulation of neurosecretory material, mainly in the bodies and processes of the neurosecretory neurons. In postnatal ontogenesis, the response of the neurosecretory system to sugar loading is less clearly visible.

The response of the hypothalamo-hypophyseal neurosecretory system (HHNS) to experimental factors consists either of its emptying or of the deposition of neurosecretory material (NSM) in the hypothalamic neurons and neurohypophysis. To study the development of this response of the HHNS in ontogenesis, factors leading to the accumulation of NSM are more convenient, for in the early stages of development of animals, the content of NSM in the HHNS is small, and its liberation cannot be accepted as proof of the existence of this response.

According to information in the literature, accumulation of NSM in the bodies and processes of neurosecretory neurons and in other parts of the HHNS of adult animals takes place under certain experimental conditions: after injections of some hormones and substances [4, 13-16], hydration and dehydration [3, 8], photic stimulation [12, 14], alloxan diabetes [10, 11, 17], sugar loading [5, 6, 15, 16], extirpation of certain glands [2, 15, 16], and so on.

Sugar loading was chosen as the experimental factor used to investigate the response of the HHNS in ontogenesis.

EXPERIMENTAL METHOD

Male rats weighing 180-200 g and young rats aged 10 and 20 days were used in the investigation. The experimental animals received 5 or 10% sugar solution daily instead of water. The adult animals were killed by decapitation after 7 and 10 days, and the young rats after 7 and 9 days. The hypothalamus and pituitary were fixed in Bouin's fluid and embedded in paraffin wax. Sections were cut to a thickness of 5 μ and stained for neurosecretion with paraldehyde-fuchsin by the Gomori—Gabe method, and counterstained with light green.

EXPERIMENTAL RESULTS

The supraoptic (SO) and paraventricular (PV) nuclei of the hypothalamus in intact adult rats contain chiefly large, pale cells with a large, pale nucleus and one or two nucleoli, frequently lying next to the nuclear membrane (Fig. 1A). Some neurosecretory cells have a dark cytoplasm of varied density. It is stated in the literature that dark cells are richer in the ribosomal component and have a higher level of synthesis.

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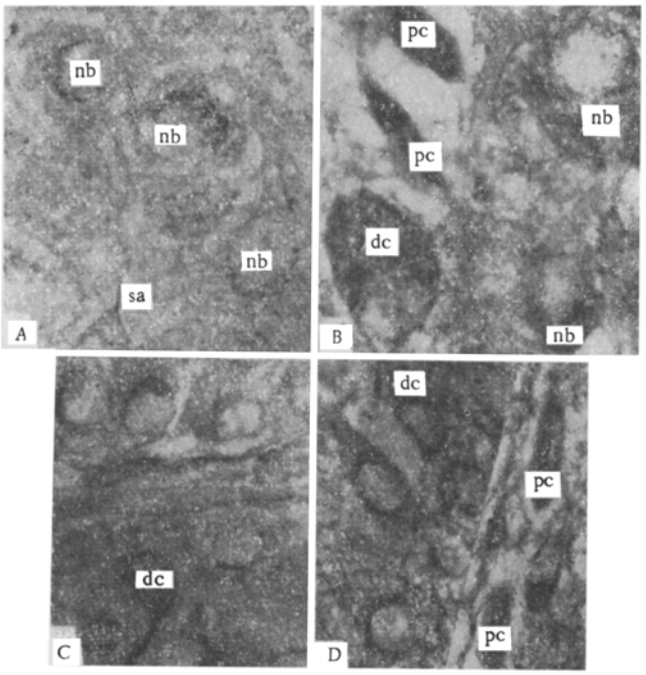

Fig. 1. Neurons of supraoptic nuclei of hypothalamus from adult control rats (A), adult experimental rats (B), 20-day control rats (C), and 20-day experimental rats (D). Legend to photographs: nb) neuron body; dc) dark cell; pc) pycnomorphic cell; sa) stained axon. Fixation of hypothalamus and pituitary in Bouin's fluid, stained for neurosecretion by Gomori—Gabe method, counterstained with light green, 630 ×.

By the arrangement and number of their neurosecretory granules the neurons can be divided into several groups, representing different phases of the secretory cycle [7, 18]. The distribution of NSM in most cells is perinuclear. Among the neurons of the SO and PV nuclei, axons filled with neurosecretion and with small swellings along their course can be seen. Close to the optic tract these stained axons are more numerous. The character of distribution of NSM in the neurons of the SO and PV nuclei resembles the arrangement of structures of the Golgi complex in them: more varied in the SO neurons and more uniform in the PV neurons [9]. In the median eminence, neurosecretory fibers of the hypothalamo-hypophyseal tract are weakly stained and there are few Herring's bodies. The neurohypophysis is filled with a dense network of deeply stained neurosecretory fibers and Herring's bodies.

Adult Rats (Experiment). On the 7th day of the experiment changes were found in the state of the HHNS compared with normal, and they were more marked at the level of the hypothalamus, especially in the SO nucleus. Later during the experiment these changes increased in severity (Fig. 1B). There was an increase in the number of dark cells with cytoplasm of varied density, ranging down to small cells with very dark cytoplasm and a dense pycnotic nucleus (Fig. 1B, dc, pc). The content of neurosecretion was increased in the neuron bodies (nb) and axons, and some axons were widened to giant size. The number of brightly stained axons was much greater in the experimental series, and the nucleoli were close to the nuclear membrane more often than in the control. In the PV nucleus the changes in the neurons were less clear, but greatly widened axons were common. No changes were found under these experimental conditions in the capillaries of the vascular network in the region of the hypothalamic neurosecretory nuclei. Appreciably deeper staining of the neurosecretory fibers of the hypothalamo-hypophyseal tract with paraldehyde-fuchsin was seen in the median eminence of the experimental rats. Herring's bodies were just as infrequent as in the median eminence of the control animals. Some increase in size and number of the Herring's bodies was observed in the neurohypophysis of the experimental rats.

Young Rats Aged 10 Days (Control). The SO nuclei of these young rats revealed greater variety of their cell forms than in rats aged 7 days [9], because of growth of the cytoplasm. Neurosecretory granules

were located mainly around the nucleus, but their number differed from one neuron to another. Many neurons were poor in NSM, and only solitary cells had a dark cytoplasm and a dense concentration of NSM. In neurons of the PV nucleus, little neurosecretion was present. Fibers of the tract in the median eminence were very palely stained. Neurosecretory fibers in the neurohypophysis formed a loose network with small Herring's bodies.

Young Rats Aged 10 Days (Experiment). A small increase in the content of neurosecretory granules was observed in the neuron bodies in the SO nuclei of the experimental rats, and the granules were more widely distributed through the cell. As in the control, the axons were weakly stained. The number of dark cells, some of them pycnotic, was increased. Many neurons were poor in NSM. In other parts of the HHNS of the experimental rats, no visible differences from the control could be seen.

Rats Aged 20 Days (Control). In the animals of this age, appreciable morphological differentiation of the HHNS was apparent [9] (Fig. 1B). Neurons of the SO and PV nuclei were increased in size. Variations in the size of the neurons and in the content and character of distribution of NSM in them were considerable. Dark cells were more numerous than in the SO nuclei of the 10-day rats. A delicate bundle of neurosecretory fibers of the hypothalamo-hypophyseal tract could be seen in the median eminence. The neurohypophysis contained a dense network of neurosecretory fibers, but less dense than in adult animals. Numerous small Herring's bodies were present [9].

Rats Aged 20 Days (Experiment; Fig. 1D). An increase in the content of neurosecretion was observed in the neurons of SO nuclei of the experimental rats. The number of various types of dark cells was appreciably increased, and some of these cells were small and pycnomorphic. Axons were weakly stained. Long dark cells with a dense border of neurosecretion around the nucleus were frequently seen along the walls of blood vessels penetrating into the region of the SO nucleus. Variability of the cells was less marked in the PV nuclei, and the increase in content of neurosecretion was less conspicuous. Solitary Herring's bodies were seen in the median eminence. The neurohypophysis was richer in NSM than the control, and Herring's bodies were more numerous.

Assessment of the morphological picture observed in the HHNS of adult rats and young rats aged 10 and 20 days, during sugar loading and in its absence, leads to the conclusion that under these experimental conditions there was a phase shift of the neurosecretory cycle [7, 18] toward predominance of accumulation of NSM over its liberation into the blood stream. Changes in the secretory cycle were particularly demonstrative in the SO nuclei of the hypothalamus of the adult experimental animals. They took the form of an increase in the content of NSM in the neurons (bodies and axons), and an increase in the number and variety of the dark cells. The phase shift in the secretory cycle of the 20-day rats was less marked than in the adults, but more marked than in the 10-day rats. No information was available on changes in the response to sugar loading in ontogenesis [5, 6, 15, 16]. The accumulation of NSM in the neurosecretory system under different experimental conditions has been interpreted variously by different workers: some have attributed it to the liberation of ACTH or to changes in the hormonal background [4, 14], others to excitation of the hunger and thirst centers [17], others, again, to a disturbance of carbohydrate metabolism [10, 11], and so on. Changes in the SO nuclei in these investigations were clearer than in the PV nuclei, and this was supported by the results of the present investigation. Since the principal physiological role of the SO nucleus is to maintain osmotic equilibrium, with any disturbance of water metabolism neurons of the SO nucleus must participate appropriately in the response [1]. Disturbance of the neurosecretory process by sugar loading can be assumed to result from a disturbance of carbohydrate metabolism [10, 11, 17]. However, the fact that in the present experiment the response observed in the hypothalamo-hypophyseal neurosecretory system of the 10-day rats was weaker than in the HHNS of the 20-day rats, and weaker still compared with that of adult rats, can be provisionally explained by assuming that in 10-day rats the mechanisms controlling water, mineral, and carbohydrate metabolism are not yet fully developed. Consequently, sugar loading, as the experimental model in ontogenesis, did not elicit a definite response of the HHNS in the young animals. The ability of the neurosecretory system to respond to disturbances of general metabolism from different causes evidently develops in ontogenesis parallel with the development and maturation of the HHNS. According to É. Kh. Priimak (unpublished data), ability to produce neurosecretion and afferent nervous connections have developed in only some cells of the SO nucleus in young rats in the first week of life. Other cells are undifferentiated and still incapable of a specific function. It is not yet possible to state whether the accumulation of NSM observed experimentally, which was more marked in the HHNS of adult animals and comparatively weak in the young rats, is the result of increased synthesis

of the neurohormone, or whether its deposition in different parts of the hypothalamo-hypophyseal neurosecretory system is the result of a decrease in the requirement of the hormone and, consequently, of inhibition of its liberation into the blood stream.

LITERATURE CITED

1. B. V. Aleshin, Arkh. Anat., No. 3, 15 (1970).
2. A. A. Voitkevich, Neurosecretion [in Russian], Leningrad (1967).
3. M. G. Zaks and B. I. Shapiro, in: Neurosecretory Elements and their Role in the Organism [in Russian], Moscow–Leningrad (1964), p. 165.
4. E. I. Zubkova, Probl. Éndokrinol., No. 1, 21 (1962).
5. A. L. Polenov and S. I. Yushkantseva, Dokl. Akad. Nauk SSSR, 148, No. 2, 441 (1963).
6. A. L. Polenov, in: Morphology and Cytochemistry of the Cell [in Russian], Moscow–Leningrad (1963), p. 121.
7. A. L. Polenov, in: Neurosecretory Elements and their Role in the Organism [in Russian], Moscow–Leningrad (1964), p. 6.
8. A. L. Plenov, Hypothalamic Neurosecretion [in Russian], Leningrad (1968).
9. É. Kh. Priimak and N. L. Yushkevich, Zh. Obshchei Biol., 30, No. 3, 348 (1969).
10. A. E. Rabkina, Probl. Éndokrinol., No. 3, 106 (1964).
11. E. I. Tarakanov, A. E. Rabkina, and V. F. Maiorova, Probl. Éndokrinol., No. 6, 19 (1961).
12. B. I. Shapiro and L. G. Karmanova, in: Neurosecretory Elements and their Role in the Organism [in Russian], Moscow–Leningrad (1964), p. 232.
13. I. F. Christ and E. Jarosch, Z. Zellforsch., 93, 404 (1969).
14. E. Kivalo and U. K. Rinne, Acta Endocrinol. (Copenhagen), 34, 8 (1960).
15. H. Legait, Acta Neuroveg. (Vienna), 15, 252 (1957).
16. H. Legait and E. Legait, Acta Anat. (Basel), 30, 429 (1957).
17. R. Roudier, G. Thuillier, and P. de Geine, C. R. Soc. Biol., 160, 1186 (1966).
18. D. Zambrano and E. de Robertis, Z. Zellforsch., 73, 414 (1966).