ZONAL CHANGES IN THE CIRCULATION OF THE CEREBRAL CORTEX DURING ADEQUATE STIMULATION IN CHRONIC EXPERIMENTAL CONDITIONS

N. M. Ryzhova

UDC 612.824 + 612.821.74].014.44/.45

Investigators [1, 3, 8, 9] have shown that various types of stimulation (photic, acoustic, etc.) produce an increase in the blood flow in the anesthetized animal in the corresponding projection zones of the cerebral cortex. In acute experimental conditions these reactions of the cerebral vessels are not accompanied by behavioral reactions. However, the reaction of the waking animal to a particular type of stimulus is more complex in character, and accordingly the changes in the cerebral circulation may be more generalized. Few investigations of this problem have been made [7].

The hemodynamic correlates of the reactions of the central nervous system can be studied most fully in chronic experimental conditions. An attempt was therefore, undertaken to determine to what degree the principle of zonal redistribution of the blood flow is represented in the waking animal by changes in the cerebral circulation. Attention was also directed to the relationship between the zonal changes in the cerebral blood flow and changes in the general arterial pressure brought about by well marked behavioral reactions.

EXPERIMENTAL METHOD

Experiments were carried out on seven waking cats with permanently implanted flat thermoelectrodes [4] in the optic and auditory areas of the cortex and with a catheter implanted in the right carotid artery. The thermoelectrodes and catheter were implanted in sterile conditions under Nembutal anesthesia (30 mg/kg). Holes were drilled in the bones of the skull in the region of the auditory and optic cortex, and the thermoelectrodes were cemented in them. The leads from the thermoelectrodes were taken under the skin and connected to the terminals of a miniature junction, also fixed to the skull. A polyethylene catheter with a bore of 1 mm, filled with Ringer's solution with heparin [6], was introduced through the carotid artery as far as the aorta, and its other closed end was fixed in the occipital region. The main part of the experiment was carried out one or two days after the operation. The changes in the cerebral blood flow were recorded by means of the thermoelectrode on a photokymograph. The arterial pressure and respiratory movements were recorded by appropriate detectors on a "Galileo" multichannel electrocardiograph. The wires and tubes connecting the animal to the instruments were suspended from a system of pulleys allowing free movement of the cats inside the chamber. Altogether 43 experiments were carried out on waking animals and 12 control experiments on cats anesthetized with urethane.

EXPERIMENTAL RESULTS

The first observations showed that in the waking animal, as also in the anesthetized [1, 8, 9], in response to photic stimulation, the blood flow was selectively increased in the occipital region of the cortex. The results of an experiment in which the blood flow was recorded simultaneously in the optic and auditory areas of the cortex are given in Fig. 1A. During photic stimulation, the blood flow in the occipital region was clearly increased whereas the blood flow in the parietal region, the arterial pressure, and the respiration remained unchanged. The results of an experiment in which the blood flow increased faster than after 1 sec — are given in Fig. 1C. The selective character of the reaction of the cerebral vessels was also exhibited during acoustic stimulation. During this, as during photic stimulation, no significant changes were found in respiration and the arterial pressure (Fig. 1D). Another similarity of the zonal reactions of the

Laboratory of Physiology and Pathology of Respiration and the Circulation, Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR, Moscow (Presented by Academician V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 64, No. 7, pp. 9-13, July, 1967. Original article submitted August, 1966.

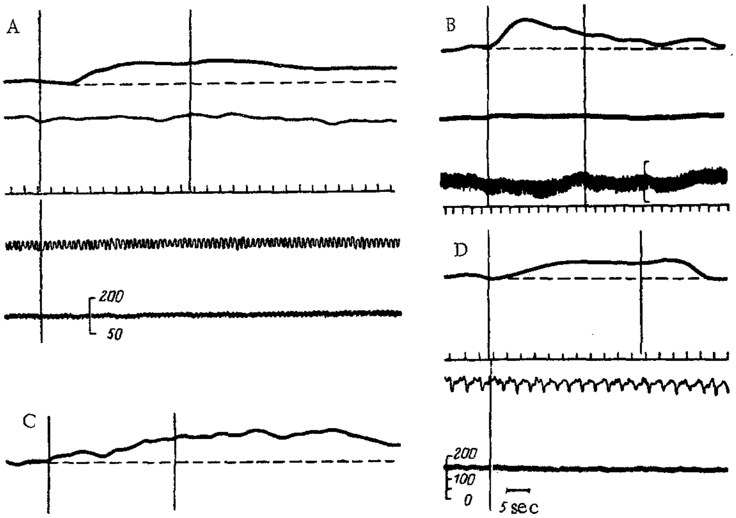

Fig. 1. Increase in the blood supply of the optic and auditory areas of the cerebral cortex during photic and acoustic stimulation. A, C, D — Waking cat, B — anesthetized cat. From top to bottom: A — blood flow in the optic cortex, blood flow in the auditory cortex, time marker (5 sec), restoration, arterial pressure; B —blood flow in the optic cortex, blood flow in the auditory cortex, arterial pressure, time marker (5 sec); C — blood flow in the optic cortex; D — blood flow in the auditory cortex, time marker (5 sec), respiration, arterial pressure. The broken line represents the initial level of the blood flow, the vertical lines the beginning and end of stimulation.

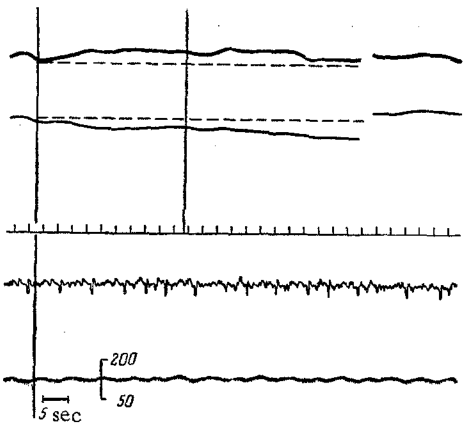

Fig. 2. Reactions of the blood vessels of the optic and auditory areas of the cortex in opposite directions during photo stimulation. Order of the tracings as in Fig. 1A.

brain vessels of the waking and anesthetized animals was that these reactions were not accompanied by general hemodynamic changes and, consequently, they were active in character. The increase in blood flow, limited to one single projection zone, thus, reflects a nervous process taking place locally. Reports in the literature also suggest the active character of the reaction of the cerebral vessels to excitation [5].

However, the zonal reactions of the cerebral vessels of the waking animal differed essentially from the reactions observed in acute experiments. This difference lay in the prolonged after-effect (compare Fig. 1A and Fig. 1B). In some investigated animals, in response to the same stimulus (photic, for example,) changes in the blood flow appeared in both the optic and the auditory zones of the cortex (Fig. 2). In these circumstances, however, the reactions were always opposite in direction, i.e., an increase in the blood flow in the occipital region was accompanied by a decrease in the auditory cortex. Similar reactions in opposite directions were described in acute experiments by B. N. Klozovskii [2], and by E. D. Antoshkina and A. I. Naumenko [1]. It may be postulated that the decrease observed in the blood flow in the auditory zone was due to a simultaneous depression of the nervous activity in this zone. However, the possibility is not ruled out that this decrease in the blood flow in the unexcited part of the cortex was caused by local hemodynamic factor.

A highly characteristic fact discovered in the experiment on waking animals was that if the animal was called by name (Fig. 3A), shown an albino mouse (Fig. 3B), or subjected to other changes in the experimental environment, well defined zonal reactions always appeared. Only if the behavioral reactions were well

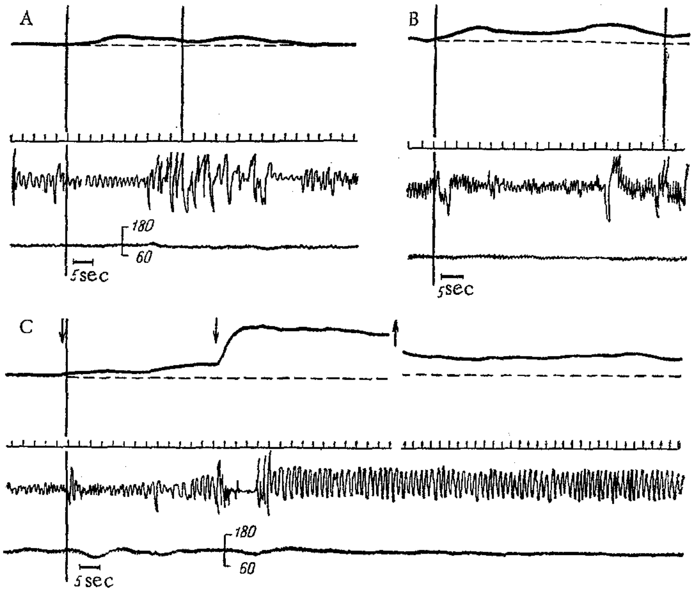

Fig. 3. Reaction of the vessels of the auditory cortex to calling the cat by name (A), and reactions of the optic cortex to showing an albino mouse (B) and a dog (C). From top to bottom: A — blood flow in the auditory cortex, time marker (5 sec), respiration, arterial pressure; B and C — blood flow in the optic cortex, time marker (5 sec), respiration, arterial pressure.

marked were significant changes observed in the arterial pressure and the rhythm of restoration. The reaction of the vessels in the occipital cortex, the respiration, and the arterial pressure to the sight of a dog is illustrated in Fig. 3C. The appearance of the dog by the experimental chamber (first arrow) numbed the cat to some extent, and this was accompanied by an increase in the blood flow of the optic cortex and a decrease of the arterial pressure. Barking of dogs (the second arrow) led to an aggressive reaction of the cat. This reaction was accompanied by a marked increase in the blood flow in the optic cortex, by inhibition of respiration, and by a fall of arterial pressure. In this case also, the zonal reaction was evidently active in nature, for the increase in the blood flow in the optic cortex was not accompanied by an equally marked increase in arterial pressure. The after-effect in this case was also well defined. These findings indicate that the zonal reactions of the cerebral vessels are to a definite degree independent of general hemodynamic changes.

LITERATURE CITED

1. E. D. Antoshkina and A. I. Naumenko, Fiziol. Zh. SSSR, No. 11, 1305 (1960).
2. B. N. Klosovskii, The Saturation of the Blood in the Brain [in Russian], Moscow (1951).
3. L. A. Lugovoi, Byull. Éksp. Biol., No. 10, 11 (1964).
4. M. E. Marshak, Byull. Éksp. Biol., No. 1, 121 (1957).
5. G. I. Mchedlishvili and L. S. Nikolaishvili, Fiziol. Zh. SSSR, No. 4, 380 (1966).
6. K. Turanski, Byull. Éksp.Biol., No. 7, 99 (1962).
7. E. Kanzow and D. Krause, Pflüg. Arch. Ges. Phydiol., Bd 274, S. 447 (1962).
8. J. S. Meyer and F. Gotoh, Neurology (Minnicap.), 11, N 4, Pt. 2 (1961), p. 46.
9. H. M. Serota and R. W. Gerard, J. Neurophysiol., 1, 115 (1938).