EFFECT OF HYPOTHERMIA ON RESISTANCE TO THE BLOOD FLOW IN THE CEREBRAL VESSELS AND THEIR RESPONSES TO NEUROHUMORAL STIMULI

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UDC 612.824-06 : 612.592

Experiments on cats showed that at the beginning of development of hypothermia the resistance to the blood flow in the cerebral vessels rises and remains high throughout the period of development of hypothermia and subsequent restoration of the initial body temperature. Hypothermia depressed the responses of the cerebral vessels to nervous and, to a lesser degree, humoral stimuli.

Hypothermia is known to be accompanied by a decrease in the cerebral blood flow [3, 4, 6-8, 10, 11, 16]. If, however, it is remembered that the volume of blood flowing through the brain depends on the resistance of the cerebral vessels and also on the level of the systemic arterial pressure which is significantly reduced during hypothermia, it is by no means always possible to be sure of the cause of the observed decrease in the cerebral blood flow.

The object of the present investigation was to continue the study of this problem and also to investigate the effect of hypothermia on some indices of the state of neurohumoral regulation of vascular tone in the brain.

EXPERIMENTAL METHOD

Experiments were carried out on cats anesthetized with chloralose and urethane, using the resistography method. The blood vessels of the brain were perfused with blood from the same animal through both external carotid arteries; the vertebral arteries and extracerebral branches of the carotid arteries were ligated.

Afferent fibers of the vagus and sciatic nerves were stimulated with square pulses (50/sec, 10 msec, 0.5-10 V). Adrenalin and noradrenalin were injected into the systemic circulation in doses of 1-5 μg/kg. Hypothermia was produced by cooling through the skin or by extracorporeal cooling of the blood in a heat-exchanger. The body temperature of the animals was lowered to 26-25°C.

EXPERIMENTAL RESULTS

The 11 experiments of series I showed that at the beginning of cooling the tone of the cerebral vessels rose sharply, and then remained high throughout the period of hypothermia, falling only slightly when the temperature was 27-25°C. Subsequent reheating of the animals was accompanied by a further increase in the perfusion pressure, which remained high even after the normal body temperature had been restored (Fig. 1).

These results are in agreement with the opinion of those workers who concluded from determination of calculated values for the resistance to the blood flow that hypothermia is accompanied by constriction of

Laboratory of Pathophysiology of the Circulation, N. D. Strazhesko Institute of Clinical Medicine, Kiev. (Presented by Academician of the Academy of Medical Sciences of the USSR N. N. Gorev.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 72, No. 8, pp. 15-17, August, 1971. Original article submitted September 2, 1970.

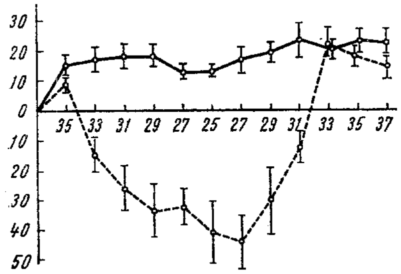

Fig. 1

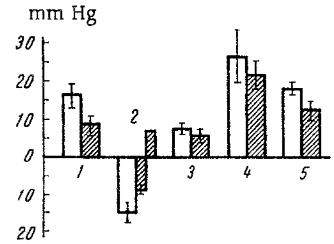

Fig. 2

Fig. 1. Dynamics of level of perfusion pressure (M ± m) in major arteries of brain when isolated hydrodynamically (continuous line) and when not so isolated (broken line) during cooling and reheating of animals. Abscissa, body temperature (in °C); ordinate, pressure (in mm Hg).

Fig. 2. Changes in pressor and depressor responses of cerebral vessels during hypothermia (M ± m). Unshaded columns show responses at normal body temperature; shaded columns show responses during hypothermia. 1) Intensive stimulation of vagus nerve; 2) the same during stimulation by current of low amplitude; 3) stimulation of sciatic nerve; 4) injection of adrenalin; 5) injection of noradrenalin.

the cerebral vessels [5, 9, 12-14]. However, the opposite opinion is also held, according to which hypothermia causes dilatation of the cerebral vessels [1, 17]. This view is based on experiments in which the hydrodynamic link between the extracranial and intracranial vessels was not severed, so that it cannot be reliably used to judge the responses of the cerebral vessels.

In the five control experiments of series II, both carotid arteries were perfused without preliminary ligation of their extracerebral branches. The perfusion pressure recorded under these conditions reflected the total resistance to the blood flow in vessels of different tissue of the head, including the brain. The results differed sharply from those of the experiments of series I examined above. The perfusion pressure in the vessels of the head was increased only at the beginning of cooling and at the end of reheating. Throughout the period of hypothermia and the beginning of reheating the perfusion pressure remained below its initial level (the broken line in Fig. 1). The results of these experiments indicate the importance, when studying the cerebral circulation, of isolating it from the extracerebral blood flow, and they explained why in certain investigations undertaken without observance of this rule, results were obtained which indicated dilatation of the "cerebral" vessels during hypothermia.

It can be concluded from the results described above that hypothermia is accompanied by constriction of the cerebral vessels. In the intact animal constriction of the cerebral vessels during hypothermia is combined with a decrease in the systemic arterial pressure, and this may reduce the cerebral blood flow still further. Despite this fact, the blood supply to the brain remains adequate, since metabolism and the oxygen demand of the brain tissue are reduced during hypothermia by a greater degree than the cerebral blood flow [15].

The increase in resistance to the blood flow in the cerebral vessels during hypothermia cannot be attributed to increased viscosity of the blood, for side by side with an increase in resistance in the cerebral vessels in these experiments, the resistance in the vessels of the small intestine and heart and, in most experiments, in the vessels of the skeletal muscles also was reduced [2]. In addition, during the reheating period, the blood viscosity fell although the resistance of the cerebral vessels remained high. The present results also indicate that there is no direct relationship between the increase in resistance of the brain vessels and the decrease in the level of metabolism in them. Whereas the oxygen demand of the brain fell as hypothermia deepened, and rose gradually with restoration of the body temperature [15], the resistance of the cerebral vessels increased by the greatest degree at the beginning of cooling (about 35°C), falling slightly when the body temperature was 27-25°C. In addition, during the period of gradual restoration of the initial body temperature the resistance to the blood flow in the cerebral vessels continued to rise, although brain metabolism during this period was increased. It may be considered that the increase in resistance to the blood flow in the cerebral vessels was due to the influence of hypothermia on the mechanism regulating the cerebral circulation.

In the experiments of series III, conducted on 12 cats, the effect of hypothermia was studied on responses of the cerebral vessels to nervous and humoral stimuli. Strong stimulation of the central end of the divided vagus nerve caused not only an increase in the systemic arterial pressure, but also definite constriction of the cerebral vessels, which fell significantly during hypothermia (Fig. 2). During weaker stimulation of the same nerve, the arterial pressure fell and this was accompanied by depressor responses of the brain vessels, which were significantly reduced during hypothermia or (in five experiments) converted into pressor. Meanwhile, the decrease in the magnitude of the pressure responses of the cerebral vessels to stimulation of afferent fibers of the sciatic nerve during hypothermia was not significant ($P > 0.05$). The decrease in magnitude of the pressure responses of the cerebral vessels to adrenalin also was not significant ($P > 0.5$); the response to noradrenalin, however, showed a significant decrease during hypothermia (Fig. 2).

The observed decrease in responses of the cerebral vessels during hypothermia was not attributable to worsening of the animal's general condition during the long experiment; for after reheating to the original body temperature the responses of the cerebral vessels recovered completely.

Hypothermia thus leads to a significant increase in the resistance to the blood flow in the cerebral vessels and to a decrease in their responses to nervous and, to a lesser degree, humoral stimuli.

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