TRANSMISSION OF EXCITATION IN THE INFERIOR MESENTERIC GANGLION OF THE CAT ON ALTERATION OF THE BLOOD SUGAR LEVEL

(UDC 612.893.05-019-06:612.122)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 58, No. 8, pp. 3-6, August, 1964
Original article submitted March 7, 1963

The literature devoted to the influence of changes in glycemia on the functioning of various levels of the nervous system [6, 7, 13, 14] contains little information on the transmission of excitation in the sympathetic ganglia under these conditions. This problem is of great theoretical and practical interest.

Ganglionic transmission is effected by a whole series of physicochemical processes, the synthesis, release, and hydrolysis of acetylcholine playing an important role. According to numerous data, the synthesis of acetylcholine by nerve tissue is closely related to carbohydrate metabolism and the transformations of macroergic phosphorus compounds associated with it [5, 18].

In experiments involving perfusion of the superior cervical ganglion of the cat with Ringer-Locke's solution containing glucose, Brown and Feldberg [10] showed that continuous acetylcholine synthesis occurs on tetanization of the preganglionic nerve trunk at the ganglionic-synapse level. The transmission of excitation deteriorates when the perfusate contains no glucose [17]; this results either from a decrease in acetylcholine synthesis [15] or from an attenuation of the reaction of the cholinergic ganglionic structures to acetylcholine [19].

In these works the data were obtained during perfusion of the ganglion, which to some extent disrupts the metabolism of the neural structures [19]. In addition, the humoral influences which the organism exerts on the ganglion are eliminated under these conditions.

When the blood supply of the superior cervical ganglion of the cat is left undisturbed the excitation threshold of the preganglionic fibers and the amplitude of the contractions of the nictitating membrane on supernormal stimulation do not vary noticeably in the presence of hypoglycemia [4]. However, as was shown in another work [9], hypoglycemia reduces the functional lability of the ganglionic cells under such conditions.

We set ourselves the task of making a more detailed investigation of the ganglionic transmission of excitation in the intact organism in the presence of varying degrees of hyperglycemia and aggravated insulin hypoglycemia.

EXPERIMENTAL METHOD

Our work was conducted on 50 mature cats under acute experimental conditions; the animals were under chloralose-urethane anesthesia (60 + 500 mg/kg). Some of the experiments were performed on spinal animals. The subject of our investigation was the inferior mesenteric ganglion of the cat. We stimulated the 2nd inferior splanchnic nerve (n. splanchnici inf.) and used the ipselateral hypogastric nerve (n. hypogastricus) as the lead following Lloyd's scheme [16]). The preganglionic sympathetic trunk was stimulated with supermaximal square pulses of varying frequency for 0.1 msec. The action currents were taken off through implanted platinum electrodes, which remained fixed to the nerves throughout the entire experiment. The electrograms were recorded on parallel-connected ENO-1 and MPO-2 oscillographs, with the aid of a UBPI-01 amplifier.

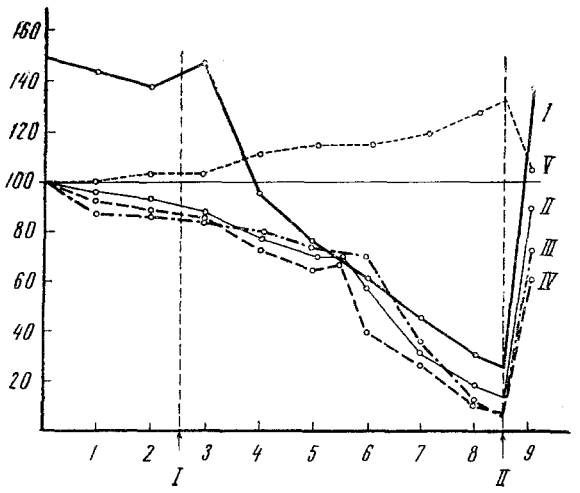

Fig. 1. Dynamics of electrophysiological indices of conduction of excitation through the inferior mesenteric ganglion in developing hypoglycemia (averaged data from 15 experiments). The values of the electrophysiological indices (in % of the initial value) and the blood sugar level (in mg-%) are shown along the ordinate. The time in hours is shown along the abscissa. 1) Blood sugar; 2) lability; 3) excitability; 4) functional resistance; 5) latent period of reaction. The arrows indicate: I) injection of 5-10 units of insulin; II) injection of 2-5 ml of 40% glucose.

The hyperglycemia was induced by intravenous injection of a 40% glucose solution (0.5-5 ml), while the hypoglycemia was produced by injection of insulin (5-10 units/kg). The blood sugar content was determined by the Hagedorn-Jensen method.

EXPERIMENTAL RESULTS

Insulin hypoglycemia is accompanied by a gradual deterioration of the transmission of excitation in the sympathetic ganglion. During the first 3 h after injection of insulin, when the blood sugar level drops from 140-150 to 75-65 mg-%, there is a gradual decrease in the excitability of the preganglionic nerve trunk and a drop in lability from 60-80 to 30-35 stimuli per second. The so-called functional resistance of the neural substrate [2], i.e., the ability of the ganglion to conduct high stimulation frequencies for a prolonged period (Fig. 1), is also reduced. A slight rise in lability is occasionally observed at the end of the first period of hypoglycemia.

In more marked hypoglycemia, when the blood sugar content is reduced to 35-30 mg-% or less, the excitability, lability, and functional resistance drop sharply and almost complete blocking of ganglionic excitation transmission sets in (Fig. 2).

Cutting short the insulin hypoglycemia by injecting glucose into the bloodstream more or less completely restores ganglionic excitation transmission (see Fig. 1).

Insulin hypoglycemia thus reduces the functional lability of the cells of the sympathetic ganglion. The periodicity which we noted for this process may be attributed not only to the increasing influence of the low blood sugar level on the various elements of the ganglion, but also to compensatory processes, which, judging from the data in the literature, consist in hyperadrenalemia [1, 11, 20].

In the experiments involving hyperglycemia we also found that the values of the bioelectric characteristics were a clear, statistically reliable function of the blood sugar content. Beginning at a level of 400-600 mg-% or more the pessimum shifts toward lower frequencies and functional resistance decreases (Fig. 3).

The blocking of synaptic transmission at high blood sugar contents may apparently be caused by reversible "glycogen pseudohypertrophy" of the presynaptic endings [8] or by disturbances of the acetylcholine cycle [3, 12].

It follows from our experiments that there is a range of normal blood sugar level fluctuations (70-300 mg-%) within which there is no marked disruption of ganglionic excitation transmission. Either a decrease or an increase in blood sugar content causes a deterioration of ganglionic excitation transmission.

Taking into account the fact that the dependence of the functional lability of nerve cells on disruptions of carbohydrate metabolism is apparently manifested to a greater extent under functional stress, in a number of experiments we conducted prolonged stimulation of the preganglionic trunk at optimum frequencies. In hypoglycemia (40-50 mg-%) the ability of the ganglionic cells to reproduce the optimum stimulation frequencies for an extended period was sharply reduced. Even at a frequency of 20 stimuli per second fatigue usually set in within 3-5 min, while in the control experiments this frequency could be reproduced without transformation or loss of amplitude for 30 min or more. Against a background of fatigue a single injection of 0.1 ml of 0.1-0.4% glucose into the a. mesenterici inf. increased the amplitude of the responses. This restorative effect lasted 30-60 sec. When the hypoglycemia became more severe the restoration was briefer and less marked.

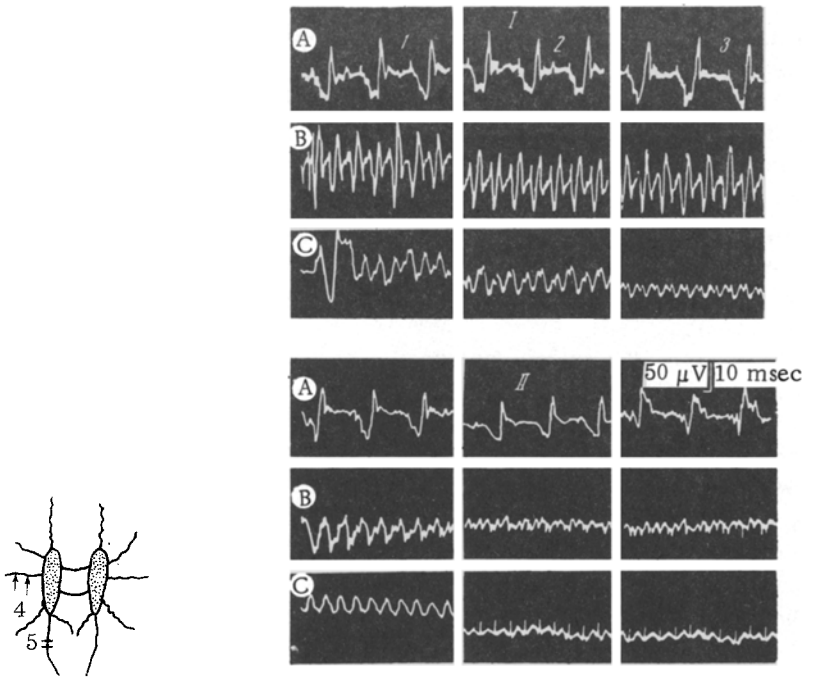

Fig. 2. Potentials of the postganglionic fibers of the inferior mesenteric ganglion. I) Before injection of 5 units of insulin; II) 4.5 h after injection of insulin (blood sugar content—50 mg-%). Stimulation frequencies: A) 15 stimuli per sec; B) 30 stimuli per sec; C) 60 stimuli per sec. Time from beginning of stimulation, in seconds: 1) 1 sec; 2) 2 sec; 3) 10 sec. The diagram at the left shows the positioning of the electrodes on the inferior mesenteric ganglion: 4) stimulating electrodes; 5) take-off electrodes.

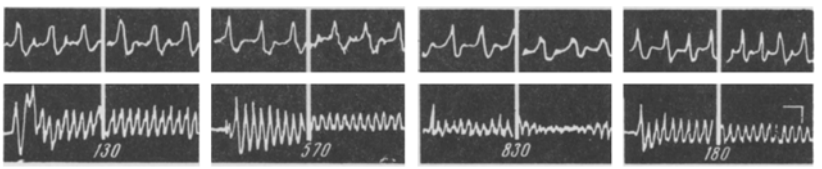

Fig. 3. Potentials of the postganglionic fibers of the inferior mesenteric ganglion in hyperglycemia. The numerals at the bottom indicate the blood sugar content (in mg-%). A) Stimulation frequency of 15 stimuli per sec; B) 60 stimuli per sec. The amplitude marker is 50 μV and the time marker 50 msec.

SUMMARY

The electrophysiological indices of transmission through the inferior mesenteric ganglion during hypo- and hyperglycemia were studied in experiments on 50 spinal and anesthesized cats (urethane and chloralose). It was shown that the decrease in the blood sugar level was accompanied by a certain decrease in the sympathetic ganglia lability and functional resistance. It was possible to see two stages in the course of this process: 1) slow decrease in lability and, 2) fast decrease in lability. During the hyperglycemia the ganglionic transmission also decreased.

The normalization of glycemia improved ganglionic transmission.

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