CHANGES IN MYOCARDIAL TROPHICS DURING THE CHRONOTROPIC EFFECT

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We showed in a previous communication [1] that under the influence of the dynamic cardiac nerves a change occurred in a number of biochemical activities of the myocardium: tissue respiration, content of glycogen, adenosinetriphosphate (ATP) and creatine phosphate (CP). These changes evidently result from rearrangement of biochemical processes under the influence of the trophic action of the dynamic cardiac nerves.

The present work is concerned with the study of the effect of "rhythmic" nerves which elicit the chronotropic effect, i. e., changes in cardiac rhythm, on the state of the same biochemical factors (tissue respiration, ATP, CP, inorganic phosphorus (IP), glycogen).

Investigations carried out by A. V. Kibiakov and collaborators [2] showed that the "dynamic" and "rhythmic" nerves supplying the heart, whose anatomic entity was proved by I. P. Pavlov, differed also in the mechanism of their action upon the heart. Thus, the inotropic effect of the dynamic nerves is mediated by the essential participation of chemical agents – sympathin and acetylcholine; the rhythmic nerves, however, do not change their influence on the heart even on sharply decreasing the concentration of chemical mediators. It naturally appeared interesting to compare the effect on myocardial trophics of the rhythmic and dynamic nerves – these anatomically independent nervous units whose effect on the object innervated is evidently mediated by different factors.

EXPERIMENTAL METHOD

The experimental method has been described in a previous report. Dogs were used as experimental animals. A total of 56 experiments were performed: 32 with stimulation of the nerves and 24 controls.

EXPERIMENTAL RESULTS

The data obtained by biochemical investigations of the myocardium during positive chronotropic effect of the "rhythmic" sympathetic nerves are summarized in the diagram shown in Fig. 1.

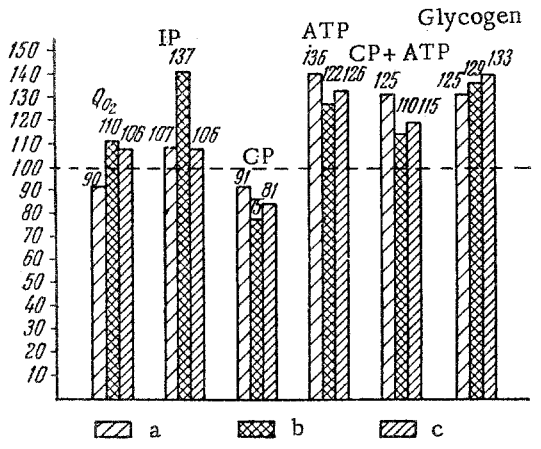

Fig. 1. Changes in the biochemical indices of the myocardium during prolonged chronotropic effect. a) 1st min of stimulation; b) 2nd min of stimulation; 3) 3rd min of stimulation. Figures are given in percentages.

The diagram is based on the arithmetic mean data calculated as percentage of controls. It shows that tissue respiration underwent a diphasic change: initial fall (1st min), followed by a slight rise. The ATP content remained higher than in the control experiments; resynthesis of ATP evidently occurred at the expense of CP whose content remained below the control value throughout the stimulation. According to Chang's findings [3] the mechanical activity of the heart depends mostly on the CP content, and this was confirmed by our experiments.

The amount of glycogen during positive chronotropic effect was increased compared to the control and remained so without significant fluctuations. The dynamics of the changes in tissue respiration and CP content during positive chronotropic effect on the heart led us to the suggestion that acceleration was accompanied by less economic cardiac contraction with the

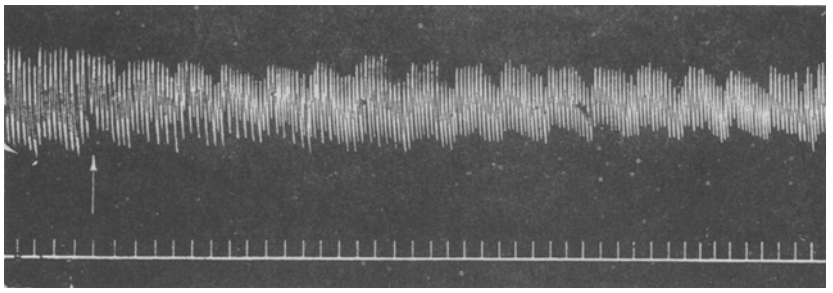

Fig. 2. Effect of stimulation of accelerator nerve (↑) on the character of cardiac activity. Records (from above down): cardiac contractions, time marker (1 sec).

loss of high-energy bonds not fully restored. This may be the very reason for the cardiac exhaustion observed on prolonged action of accelerating nerves. I. P. Pavlov [4] showed that purely accelerator branches, when excited, "diminished the blood flow and the work of the heart."

Figure 2 shows the cardiogram taken from one of the experiments in which stimulation of the accelerator nerve, as well as the corresponding biochemical tests (experiment No. 70, January 5, 1954, see Fig. 1) were carried out. As can be seen from Fig. 2, stimulation of the nerve led to acceleration of the cardiac contractions without an increase in their amplitude, but rather with a slight decrease of the latter, which evidently indicates that purely accelerator nerves were stimulated without admixture of enhancing fibers. Marked reduction of respiration (by 54%) was noted during this, as well as decrease of the CP content by 89%, increase of IP by 127.5% and ATP by 147.9%; the glycogen content also rose by 159%.

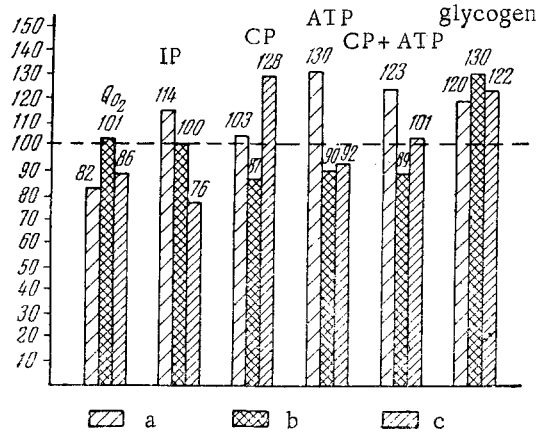

Fig. 3. Change in biochemical indices of the myocardium during negative chronotropic effect. a) 1st min of stimulation; b) 3rd min of stimulation; c) 4th min of stimulation.

The biochemical changes noted during negative chronotropic effect of the "rhythmic" parasympathetic nerves were somewhat different in character from those described: respiration was depressed; the CP content decreased during the 3rd min of stimulation and increased during the 4th; the amount of ATP rose during the 1st min and decreased during further stimulation of decelerator nerve; the IP content, slightly increased during the 1st min of stimulation, gradually decreased; the amount of glycogen rose. The described biochemical changes in the myocardium during a negative chronotropic effect are illustrated in a diagram (Fig. 3); a cardiogram is also presented (Fig. 4).

As can be seen from Fig. 4, stimulation of the nerve led to slowing the rate of cardiac contractions without diminishing their strength. This was associated with an increase in the amount of glycogen by 192%, ATP by 129%, CP by 125% and a slight reduction of IP to 91%.

On the basis of the data obtained, it is thus possible to suggest that the character of the biochemical changes in the myocardium which occur on activation of the rhythm-controlling nerves differs from those changes which are observed during the inotropic effect of the dynamic nerves. Evidently the rhythmic nerves (in contrast to the dynamic nerves) do not produce profound changes in the myocardium which are associated with reorganization of those processes which ensure the energy supply to the heart muscle. During positive chronotropic effect the resynthesis of ATP utilized during contraction of the heart muscle occurs chiefly at the expense of CP which acts as reserve source of high-energy bonds for both the skeletal and cardiac musculature; the mechanical activity of the heart therefore depends on the content of CP.

During negative chronotropic effect the biochemical changes are not great; expenditures incurred during systole are restored during the period of rest or even more than compensated as the result of prolongation of the period of rest between the contractions of the heart.

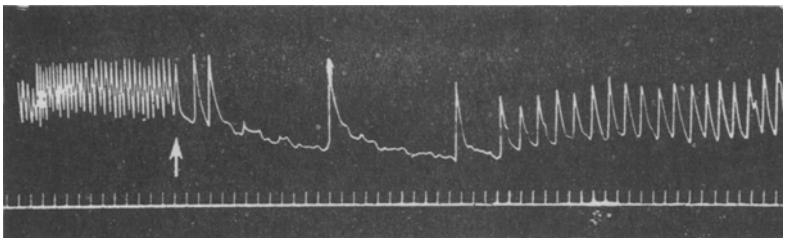

Fig. 4. Effect of stimulation of decelerator nerve on the character of cardiac activity. Records from above down: cardiac contractions, time marker (1 sec). ↑ – time of stimulation.

It is suggested that the rhythmic nerves lead only to certain quantitative changes in the biochemical indices which result from changes in the conditions of cardiac function and not special and profound biochemical reorganization.

SUMMARY

An experimental study was carried out on the effect of rhythmic nerves (causing chronotropic effect) on the change of the cardiac rhythm and tissue respiration, the content of ATP, CP, inorganic phosphorus and glycogen. In positive chronotropic effect, resynthesis of ATP expended on contraction of the cardiac muscle takes place mainly by utilization of CP which is a reserve source of high-energy bonds both for the skeletal and the cardiac muscles. Therefore, the mechanical function of the heart depends on CP content.

In negative chronotropic effect the biochemical changes in the myocardium are insignificant.

In the authors' opinion the rhythmic nerves bring about certain quantitative changes of the biochemical indicaters which are the result of changes in conditions of cardiac function and not special and profound biochemical reorganization.

LITERATURE CITED

[1] A. V. Kibiakov, The Nature of the Regulatory Influence of the Sympathetic Nervous System* (Kazan, 1950).

[2] I. P. Pavlov, Collected Works* (Moscow-Leningrad, 1951), vol. 1, p. 432.

[3] J. Chang, J. Physiol. 91, 314 (1937).

* In Russian.