PHYSIOLOGY

THE INFLUENCE OF I. P. PAVLOV'S "REINFORCING" NERVE ON CORONARY CIRCULATION

M. E. Raĭskina and Z. T. Samoĭlova

Department of Pathological Physiology of the Central Institute for the Postgraduate Training of Physicians (Chairman: V. P. Lebedeva) and Laboratory of Pathological Physiology (Director: Prof. V. V. Parin) of the Institute of Therapy of the Academy of Medical Sciences USSR, Moscow

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The nerve which reinforces heart contractions, discovered by I. P. Pavlov in 1882, was described by him as a nerve which heightens all vital activities of the heart muscle in general.

The fact that stimulation of the reinforcing nerve restored the working of a heart stopped by convallaria preparations in experiments on the whole animal and also the fact that the reinforcing nerve could act on an isolated heart drained of blood convinced Pavlov of the trophic nature of its influence on the heart.

Further work along this line by Pavlov's students [2, 3, 6] indirectly showed that the reinforcing nerve could influence the chemistry of the heart muscle.

On the other hand, the prolonged latent period noted when the reinforcing nerve was stimulated (several seconds), the similarity of the relationship between the excitability of the weakening fibers and that of the strengthening fibers when stimulated electrically to the relationship between the characteristic properties of excitability of the vasoconstrictor and of the vasodilator nerves, and, finally, the anatomical data – the distribution of the strengthening branches along the course of the coronary vessels – prompted Pavlov to suggest the possible vasomotor nature of the reinforcing nerve. However, he wrote: "Of course, the final resolution of this question must await direct experiments on the blood flow in the coronary vessels and the changes occurring in it when the various cardiac fibers are stimulated. We propose to undertake such experiments in the very near future" [5, p. 243].

But there was no further work of these experiments; nor did other data appear in the literature on the influence of the reinforcing nerve on the coronary circulation. Study of this matter was the purpose of the work described in this article.

EXPERIMENTAL METHODS

We employed Rein's thermoelectric method in Noyons' modification, which made it possible to judge changes in the rate of blood flow in vessels not opened. The recording of the rate of flow was effected with a mirror galvanometer. A thermoelectrode was attached to the left descending or left transverse branch of the coronary artery. Simultaneously with photographic recording of the rate of flow in the coronary vessels a photographic recording was made of the arterial blood pressure in the common carotid artery with a membrane manometer. At the same time, in all the experiments, the blood pressure was recorded on the smoked tape of a kymograph with a mercury and membrane manometer. An electrocardiogram in standard lead II was taken before, during, and immediately after each stimulation of the reinforcing nerve.

The reinforcing nerve was identified by us according to the scheme introduced by Pavlov. It was stimulated with an induction current from a Du Bois-Reymond coil, using a special electrode with a Hering loop to eliminate branching of the current.

In all, 22 acute experiments were performed on dogs, in which the thoracic cavity was opened under morphine-barbamyl* narcosis, including 7 experiments on heparinized dogs, using a "hemobarostat", a description of which will be given below.

EXPERIMENTAL RESULTS

The functional effect of stimulation of the reinforcing nerve, in agreement with Pavlov's findings, manifested itself in the form of a rise in the arterial blood pressure and an increase in the amplitude of the heart contractions in most of the experiments without an accompanying change in the rhythm. The arterial pressure rose 8-55 mm. In some cases the amplitude of the contractions increased to twice the original value.

In addition to this typical effect, a two-phase reaction was observed in some cases, with a depressor phase coming first. The appearance of depressor phase immediately after stimulation and the fact that it was strengthened by physostigmine and eliminated by atropine gives reason to think that its appearance is apparently connected with the presence of weakening fibers, possibly of vagus origin, in the trunk of the reinforcing nerve. It was the admixture of accelerating fibers in the reinforcing nerve that caused the appearance of the unsteady accelerating effect in our experiments and also in Pavlov's.

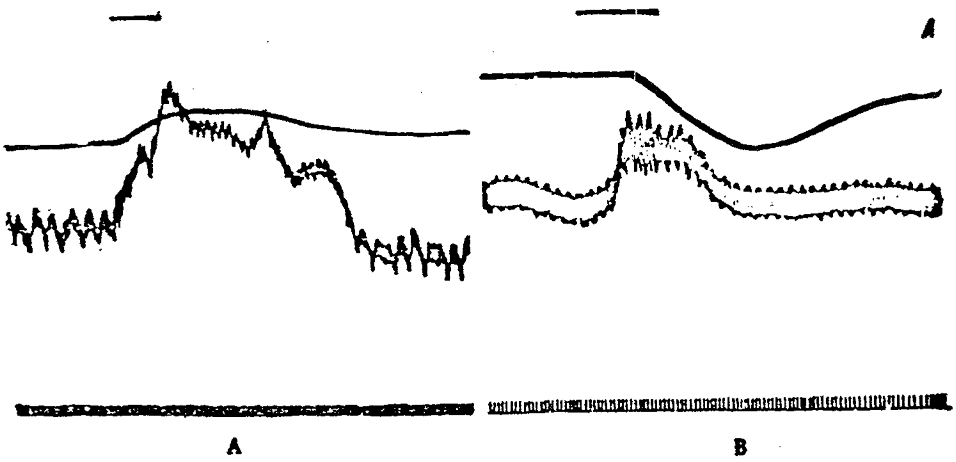

Fig. 1. Change in the coronary flow and the arterial pressure on stimulation of the reinforcing nerve. A) Increase in the coronary flow; B) decrease. Curves (top to bottom): Rate of coronary flow; arterial pressure (membrane manometer), time (in seconds). Above — periods of stimulation.

In most of the experiments the effect of stimulation of the reinforcing nerve on the coronary circulation was clearly marked. The typical effect was an increase in the rate of coronary flow; more rarely a decrease was noted, while sometimes the coronary flow showed no change (Fig. 1).

Comparison of the influence of the reinforcing nerve on the strength of the heart contractions (dynamic effect) and on the coronary flow revealed no parallelism: sometimes a relatively large increase in the rate of the coronary flow was observed with a slight positive dynamic effect, or even in the absence of such an effect.

*Barbamyl = amytal — Translator.

With repeated stimulation of the nerve, while the heart contractions were strengthened, the increase in the coronary flow became less marked, and not infrequently there was a decrease instead. When the experiment was prolonged it was possible to observe the most varied relationships between strengthening of the heart contractions and changes in the rate of coronary flow.

This permitted the supposition that when the reinforcing nerve is stimulated the dynamic and vasomotor fibers in it are stimulated at the same time. From this point of view the explanation for the most frequently observed combination, an increase in the coronary flow with a simultaneous increase in the pressure, may be that fibers strengthening the contractions of the heart muscle and fibers expanding the lumina of the coronary vessels were drawn into the stimulation simultaneously.

However, there was the possibility that the increase in the coronary flow was a passive reaction to the increase in the arterial pressure [8]. We undertook to exclude the role of an increase in the arterial pressure in the increase in the coronary flow. For this purpose we used a "hemobarostat" – an apparatus proposed by Pearce and Gowdey [9] for automatic equalization of the blood pressure when it falls in the body.

Improving certain details of the apparatus, we employed it for automatic regulation of the level of the arterial pressure as it either rose or fell in the circulatory system.

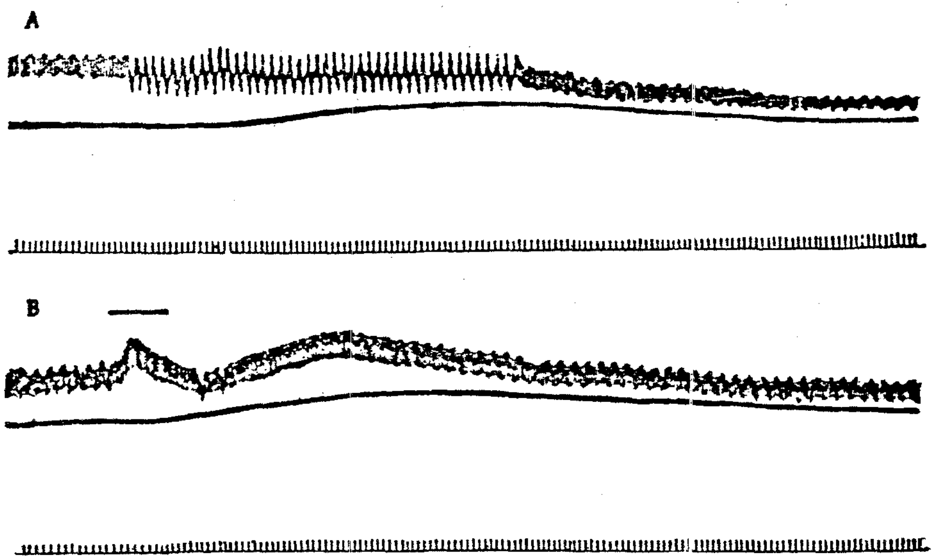

Fig. 2. Influence of the reinforcing nerve on the coronary flow: A) With the blood pressure being maintained at constant level with a "hemobarostat"; B) without the use of the "hemobarostat". Curves (top to bottom): arterial pressure; rate of coronary flow; time (in seconds). Above – period of stimulation.

The principle of operation of the apparatus consists of creating an open circulation system in which the blood pressure is kept at a constant level by using a contact mercury manometer connected through a relay with two electromagnets. By means of a mechanical arrangement one of the electromagnets, when the pressure rises, opens an outlet for the blood from the circulatory system into a reservoir in which the pressure is at a level lower than the original blood pressure; when the blood pressure drops in the animal's vascular system the other electromagnet opens an inlet for the blood into the animal's circulatory system from a reservoir in which the pressure is higher than the original pressure.

In our experiments a contact manometer was connected in parallel with a manometer recording the pressure on a kymograph. Movement of the blood from the vascular system into the compensating system and back again was effected through the left subclavian artery.

In the experiments in which the "hemobarostat" was employed we were able to establish that the changes which we observed in the coronary flow on stimulation of the reinforcing nerve may also take place in the absence of changes in the arterial pressure (Fig. 2).

Thus, the increase in the coronary blood flow on stimulation of the reinforcing nerve is undoubtedly not a passive result of the increase in arterial pressure, but the result of an active reaction caused by stimulation of vasodilator fibers entering into the makeup of this nerve.

The lack of parallelism which we established in the appearance of the dynamic and the vascular effect when the reinforcing nerve was stimulated indicates the simultaneous existence in it of fibers strengthening the heart contractions and fibers influencing the coronary flow. The appearance of the separate action of both kinds of fibers in our experiments was favored by the conditions of electrical stimulation. The vasomotor fibers are evidently more labile, and on repeated electrical stimulations they lose their irritability sooner than the dynamic fibers and cease to evoke an effect.

The fact that a strengthening effect can be obtained without a simultaneous vascular reaction evidently indicates that within definite limits it is possible for the reinforcing nerve to exert a direct influence on the metabolic processes in the cardiac muscle without an accompanying increase in the blood supply. Precisely this is indicated by the intensification of the heart contractions without an accompanying change in the coronary flow.

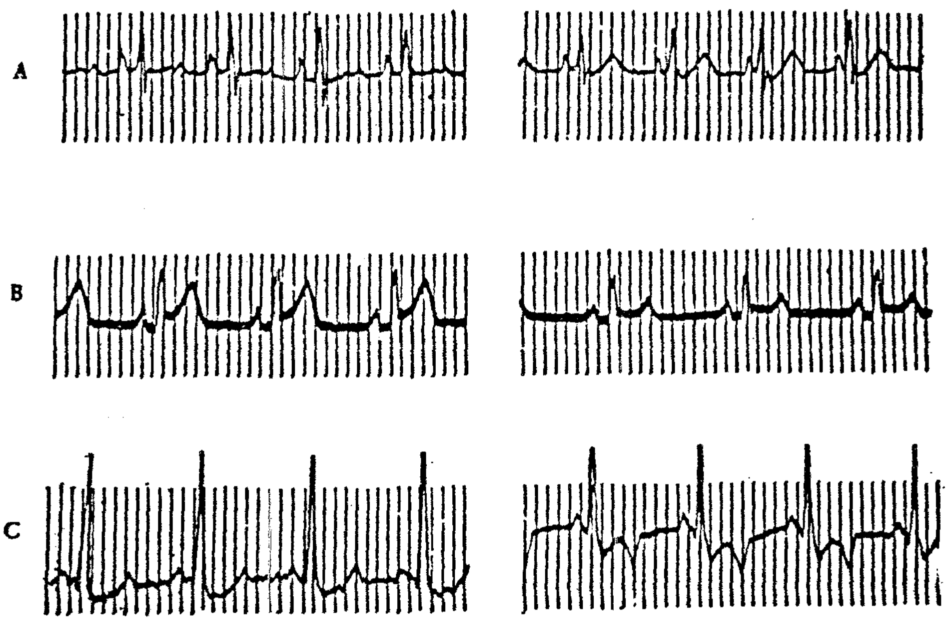

Fig. 3. Electrocardiograms before (left) and after (right) stimulation of the reinforcing nerve. A) Increase in the T wave; B) decrease in the T wave; C) change in direction of the T wave.

Under natural conditions all these kinds of influences on the strength and rhythm of the heart contractions and on the condition of the vascular system of the heart evidently combine in harmony, ensuring changes in the working of the heart to meet the demands made upon it. Under pathological conditions, however, the possibility of a selective disruption of certain nerve influences is not to be excluded.

We compared the observed reactions of the coronary flow with the electrocardiographic data. The changes in the electrocardiogram immediately after stimulation of the reinforcing nerve concerned the rhythm, and especially the final part of the ventricular complex. In our work we were especially interested in the changes of position of the S-T interval, and also in the amplitudes and directions of the T wave since, according to the current views it is precisely that reflect the condition of the blood supply of the heart. In most cases the amplitude of the T wave increased, but sometimes it decreased, and in certain cases the T wave became negative (Fig. 3). We were unable to link these changes with any certain deviations of the coronary flow from the original level; they were observed both with increases and with decreases in the rate of coronary flow, and in the absence of any changes.

Considerably less often a shift of the S-T interval downward from the isoelectric line was observed. In view of the fact that in the clinic a similar shift is considered as a sign of deficient blood supply to the myocardium, it is of interest to note that in some cases we observed changes in the S-T interval even when the rate of the coronary flow was not reduced.

Most authors think that the changes in the T wave are caused by changes in the metabolic processes connected with the recovery of irritability after the passage of the wave of stimulation [1, 4, 9, et al.]. There is also another view, according to which the causes of the changes in the T wave are to be ascribed to disruption of the nutrition of the heart muscle.

Our findings do not warrant explaining the changes which we observed in the T wave of the electrocardiogram by changes in the blood supply of the heart muscle alone. These changes are evidently connected not so much with changes in the blood supply to the heart as with the intimate trophic processes in the myocardium which are also deflected from their normal course under the influence of the reinforcing nerve.

Our findings indicate that when the reinforcing nerve is stimulated two of the mechanisms noted by Pavlov for regulation of the working of the heart muscle are included at the same time, these being the vasomotor nerves, determining the "gross delivery of chemical material", and the trophic nerves, determining, "in the interest of the body as a whole, the exact extent of final utilization of this material" [5, p. 584]. Their activity is not separate but joint, and it takes place when the reinforcing nerve is stimulated.

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*In Russian.