INTERCORONARY REFLEXES OF THE NORMAL RABBIT'S HEART

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Indirect evidence of the existence of intercoronary reflexes first appeared in 1939, when it was shown [3] that preliminary sympathectomy, vagotomy, and atropinization, and also administration of substances dilating the coronary vessels considerably lower the mortality among dogs after experimental occlusion of the coronary artery. It was concluded from these observations that the intercoronary reflexes are exclusively vasoconstrictor in their effect [4]. However, later investigations failed to confirm these findings. The mortality after experimental coronary occlusion was found to be dependent on several conditions: the rapidity of occlusion, the closeness of the point of occlusion to the "danger zones" of the heart, the type of general anesthesia, the degree of pneumothorax, and so on.

It was also found that the direct cause of death from occlusion – shock – may produce its fatal outcome as a result of the development of the reflex, first discovered by Bezold and Jarisch, from the receptors of the coronary arteries, causing a sharp decrease in the systolic ejection, dilation of the peripheral vessels, and a fall of the arterial pressure [9, 10]. The dilation of the peripheral vessels was found to extend also to the coronary system.

The direct rejection of the theory of coronary spasm was the result of investigations in which precise quantitative recordings were made of the velocity of the coronary blood flow [5-8] during acute coronary insufficiency. The usual effect in these cases was an increase in the volume velocity of the blood flow in the arteries next to that which had been clamped, and a decrease in the velocity, indicating the onset of "spasm," was seen only in the experiments using a superficial degree of anesthesia with the animal breathing normally, and also in cases of "careful, minimally traumatizing" dissection of the coronary artery [8]. More recently a tendency has gradually developed for the existence of a biphasic vascular reaction to be recognized [1, 11].

The object of the present investigation was to study the conditions of reproduction of both intercoronary reflexes in a chronic experiment by using recording methods causing minimal interference with the reactivity of the heart and of its coronary system.

EXPERIMENTAL METHOD

Reversible occlusion of the coronary artery was produced by the method devised at the Pirogov 2nd Moscow Medical Institute [2]. A midline thoracotomy was performed on rabbits under morphine anesthesia. The dissected coronary artery, supplying the anterior surface of the apex of the heart (the lower third of the anterior descending branch of the left coronary artery or of the right artery) was ligated by means of an atraumatic needle. The ends of the ligature were threaded into a polyethylene tube and exteriorized into a skin "pocket" on the anterior chest wall, and a flat miniature thermocouple was sutured to the region supplied by the artery next to the one ligated in order to record the velocity of the blood flow in the myocardium of the right or left ventricle.

A platinum electrode was sutured to the apex of the heart for recording the local electrogram. The leads from the thermocouple and the electrode were brought out under the skin along with the ligature.

Hence, in order to avoid a Bezold–Jarisch reflex (accompanied by marked changes in the arterial pressure and pulse rate) and the action of the "hemodynamic factor" observed by Wang [8], and also to strengthen the role

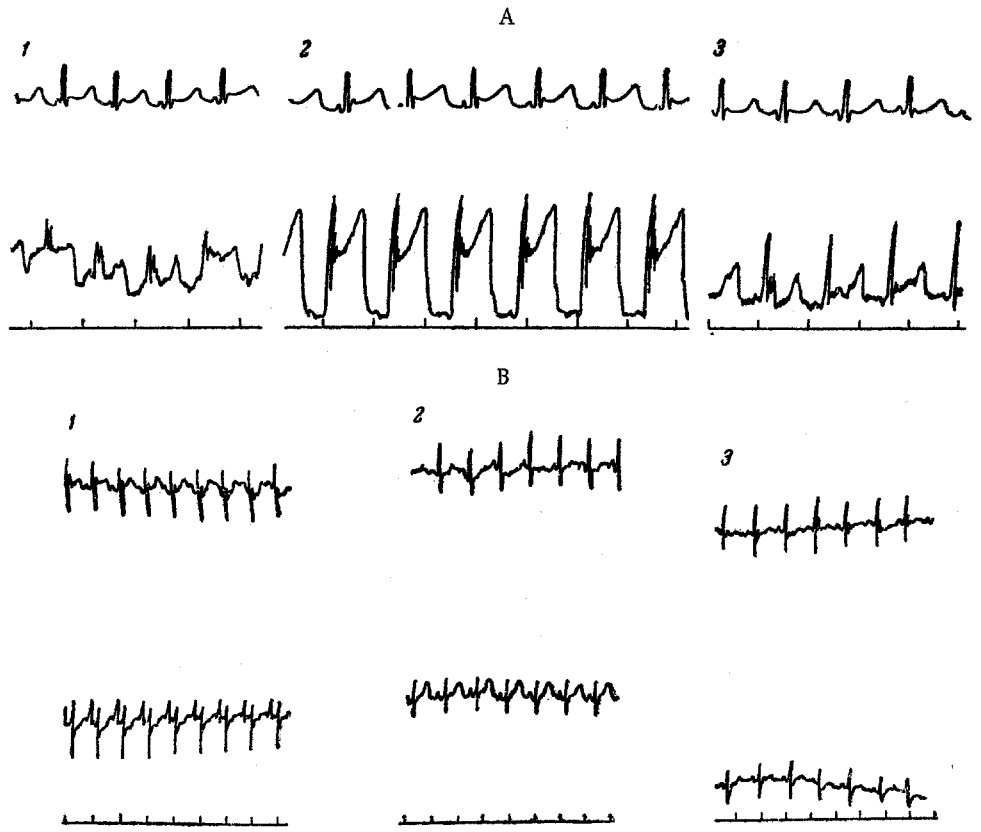

Fig. 1. Electrocardiographic effects of occlusion of the inferior third of the anterior descending branch of the left coronary artery (A) and of the peripheral branches of the right coronary artery (B). Top (in A and B)—standard leads II and III; bottom (in A and B) — local electrogram of the apex of the heart. 1) Initial tracing; 2) 2.5-3 min after occlusion; 3) 15-20 sec after restoration of blood flow.

of collaterals in the compensation of the results of occlusion, the arteries were clamped in the peripheral portions of the coronary system.

The state of the main coronary arterial trunks at the base of the heart was assessed from the position of the ST interval in standard leads II and III (restriction of the blood flow through these arteries is accompanied by elevation of the ST interval), and the state of the peripheral coronary arteries of the apex of the heart was judged from the change in the amplitude of the T wave and the position of the ST interval on the electrogram of the local lead. Changes in the tone of the coronary arteries were estimated by the thermoelectric method of Ionesco and Gibbs, the results being compared with the dynamics of the arterial pressure.

Two experiments were carried out on each of the ten normal rabbits, and during each experiment the action of 2 to 5 occlusions of a duration of 30-180 sec was studied.

EXPERIMENTAL RESULTS

Local ischemia, caused by the 1st occlusion of the right and left coronary arteries, was always accompanied by changes in the ECG. The 1st occlusion of the left coronary artery was characterized by elevation of the ST interval in the local lead (Fig. 1A) while the 1st occlusion of the right artery gave no change in the ECG or an increase in the amplitude of the T wave (Fig. 1B). Changes in the ECG in the standard leads were absent in both cases or were limited to a very slight displacement of the ST interval in leads II and III. The effects described were not accompanied by changes in the systemic pressure, and the changes in the heart rate were slight and transient.

The character of the changes in the velocity of the blood flow in the vessels next to the ligated coronary artery was remarkable for its constancy: the 1st occlusion of branches of the right coronary artery running to the apex

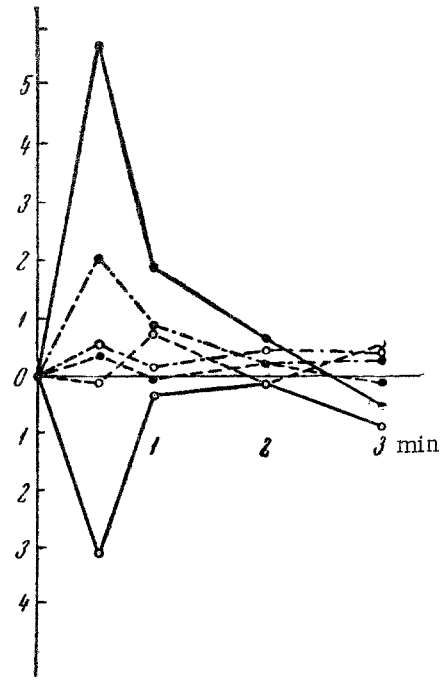

Fig. 2. Changes in the velocity of the blood flow in the area of distribution of the artery next to the ligated coronary artery (from results of the same experiments as Fig. 1). Along the axis of ordinates – relative deflections of the light spot of the galvanometer (in cm of the scale) compared with the previous time of recording; along the axis of abscissas – time (in min). Black circles) effects of occlusion of branches of right coronary artery, velocity of blood flow recorded in area of distribution of the left coronary artery; white circles) effects of occlusion of anterior descending branch of left coronary artery, velocity of blood flow recorded in area of distribution of the right coronary artery.

caused an increase in the velocity of the blood flow in the area of distribution of the left coronary artery, while the 1st occlusion of the left coronary artery was accompanied by a decrease in the velocity of the blood flow in the area of distribution of the right artery (Fig. 2).

Repetition of the occlusion of the right coronary artery led to a gradual extinction of the vasodilator effect produced by the 1st occlusion, and repetition of occlusion of the left coronary artery had a directly opposite effect: the constriction produced initially was replaced by dilatation, and this was again accompanied in the response to the 3rd occlusion by constriction.

An increase in the amplitude of the T wave is known to take place in response to smaller degrees of ischemia than elevation of the ST interval. Accordingly, the character of the reflex produced by occlusion of the coronary artery is evidently determined by the magnitude of the local ischemia developing in these circumstances: a relatively less marked ischemia leads to dilatation of the vessels next to the occluded artery, while a more marked degree of ischemia causes their constriction.

Besides the ischemic state of the myocardium, the participation of the mechanoreceptors of the chest wall, epicardium, and coronary arteries, reacting to the pull of the ligature and to the pressure of the polyethylene tube on the surface of the heart, also appears to be necessary for the development of these reflexes. However, during the analogous "occlusion" of areas of the epicardium not containing vessels visible to the naked eye, not only were signs of local ischemia not observed, but there were no changes in the velocity of the blood flow in the neighboring coronary artery.

During passage of the needle under the left coronary artery, the same changes in the ECG and in the velocity of the blood flow in the right artery were observed as during ligation of the descending branch of the left coronary artery. It may therefore be concluded that an essential role in the mechanism of the constriction observed in the area of distribution of the right coronary artery in the first 30 sec after the 1st occlusion of the descending branch of the left coronary artery is played by mechanical stimulation of the tissues surrounding the coronary vessel.

The degree of the ischemic changes in the ECG is closely connected with the intensity of mechanical stimulation of the areas of the epicardium lying next to the walls of the coronary vessels. This is confirmed by experimental data demonstrating the more abundant supply of vagus nerve receptors in the left ventricle of the mammalian heart than in the right [12].

Passage of the ligature under the right coronary artery without occlusion of the vessel was never accompanied by dilatation of the descending branch of the left coronary artery, as is usually observed during occlusion of the right coronary artery. It may therefore be supposed that the dilatation described in the area of distribution of the left coronary artery during occlusion of the right is a true intercoronary reflex.

SUMMARY

The character of the intercoronary reflexes at the apex of the normal rabbit heart was studied in a chronic experiment.

It was found that occlusion of the peripheral branch of the right coronary artery provokes dilatation of the descending branch of the left coronary artery, while occlusion of the latter causes constriction of the former. The

character of the resulting coronary reflex is closely associated with the degree of local myocardial ischemia, as well as with the strength of receptor stimulation.

It has been shown that the intercoronary reflexes in the normal rabbit heart are characterized by a high, although coordinated, variability.

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