ALTERATIONS OF HEMODYNAMIC INDICATORS AND OF THE ELECTROCARDIOGRAM PRODUCED BY EXPERIMENTAL DISTURBANCE OF THE CORONARY CIRCULATION

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The pathology of the coronary circulation has still not been exhaustively studied in extensive experiment. Some investigators in this field [4, 6, 7, 8] have studied the details of the collateral circulation within the myocardium but have not explored adequately the functional alterations produced in the coronary circulation by disturbances affecting the blood supply of the myocardium. The foreign literature also is silent on hemodynamic alterations produced in the coronary circulation by means of experimentally introduced pathology. Yet in order to develop experimentally the therapy for myocardial infarction and coronary insufficiency it is essential to have precise knowledge of those hemodynamic alterations which occur in model coronary insufficiency. Besides the theoretical significance, facts of this type have a definite interest in refining some of our concepts as to the symptomatology of myocardial infarction. This communication is devoted to an examination of the experimental material obtained in dogs who were made, artificially, to develop an insufficiency of the myocardial circulation.

EXPERIMENTAL METHODS

The experiments were conducted on adult dogs of both sexes and of varying weights. Coronary insufficiency was produced by applying a ligature to the descending branch of the left coronary artery at the juncture of its middle and lower thirds or else to the left coronary artery in the region of its bifurcation. Aseptic procedures were employed. The heart was approached by an incision below the fourth rib. Special spreaders were used to enlarge the opening. After the pleural cavity had been opened, artificial respiration was employed. The experimental dogs were followed for 40 days after surgery. At that time they were sacrificed and their hearts subjected to a searching pathological anatomical study. The electrocardiogram registered alterations in the actions of the coronary system; also, alterations in blood pressure, pulse and velocity of blood flow were recorded. The EKG was recorded in the three standard and two chest leads (V_5, V_1); the chest electrode in V_5 tracing was applied in the fifth interspace in the anterior axillary line, in the V_1 lead – in the fourth space just to the right of the sternum. The maximum blood pressure was recorded from the left carotid artery which had been previously brought out in a skin pouch. Velocity of blood flow was determined by the lobeline method.

EXPERIMENTAL RESULTS

a) EKG changes and hemodynamic alterations produced by ligation of the descending branch of the left coronary artery at the juncture of its middle and lower thirds.

The EKG picture produced by this ligation is uniform and is, basically, a change in T and the S–T interval. Table 1 summarizes the characteristic EKG changes.

The maximal blood pressure changes occurred in the acute state of myocardial ischemia (the first five days after operation) and went through two phases: on the day of ligation the blood pressure in two instances was markedly elevated, being unchanged in two others. Then, by the second day the blood pressure fell below base level remaining elevated in only one experiment, dog Blackie). Thus, for example, dog Cherny whose normal pressure was steady at 134-137 mm mercury pressure, the pressure immediately after the operation rose to 160 mm, then dropped sharply on the second day and remained within the limits of 124-136 mm.

TABLE 1

The Nature of the EKG Changes After Ligation of the Descending Branch of the Left Coronary at the Juncture of its Middle and Lower Thirds.

Dog	EKG Changes			Remarks
	Day of ligation	5 days after ligation	After 40 days	
Lex	P(2,3) enlarged T + (2, 3) Q–T enlarged T –(1) extrasystole	T + (2, 3, V_2, V_1) S–T + V_5, V_1)	Normalization	T normally is absent in (1), in others leads –
Cherny	T diminishes (2, 3, V_5, V_1) S–T + + (2, 3, V_5, V_1), extrasystole, alternating pulse	T diminishes (2, 3), Q–(2, V_5) lowered voltage	Q–(2), S–T + (2), T diminishes (2, 3, V_5), lowered voltage	
Lisa	T depressed (2, V_5), S–T + (2, V_5), P enlarged (2, 3, V_5), lowered voltage	S–T + (V_5, V_1), T + (V_5, V_1), T absent in other leads	S–T + (2, 3, V_5), T normalized voltage increased	T normal – (1, 2, 3, V_5) and + (V_1)
Zhelty	T (1, 2, 3), Q–T prolonged, extrasystoles, alternating pulse	S–T + (2, 3), T + (2, 3), depressed voltage	T–, diminished (2, 3), S–T + Q – (2, 3)	T is normal
Pesets	Polymorphic extrasystoles, tachycardia	S–T + (2, V, V), T enlarged (2, 3), diminished (V_5, V_1), lowered voltage (V_6)	S–T + (2, V_5, V_1), T depressed (V_6)	

Remarks. Here and in Table 2 the plus sign indicates relation of T wave and S–T interval to the isoelectric line. The numbers in brackets indicate the leads of EKG.

The alterations in the frequency of the heart beats had a converse character: on the day of operation the rate fell markedly (Zhelty –from 118 per minute to 58) and only in one case (Lex) there was observed a slight rise (from 88 to 104), while even here by the 4th day after ligation there was a pronounced slowing of the rhythm (to 54). In the other experiments, after the immediate postsurgical slowing, the pulse gradually returned to the preligation levels. By the end of the period of observation (40 days) there were no material deviations from the normal.

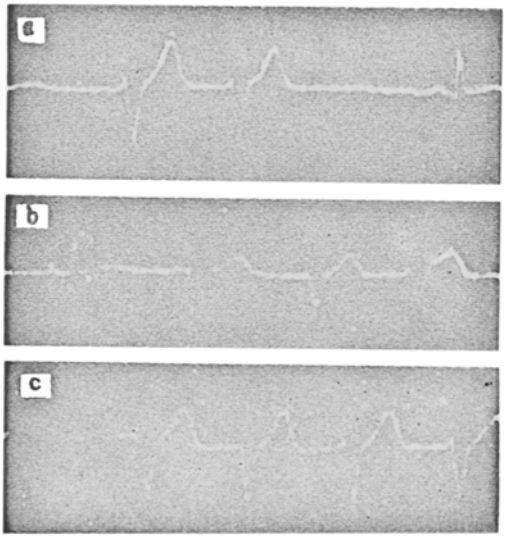

Fig. 1. Changes of EKG after ligation of the descending branch of left coronary artery at the juncture of middle and lower thirds (dog Cherny, third day after applying ligature). a) Lead II, b) lead III, c) lead V_6.

TABLE 2

Characteristic EKG Changes Occurring After Ligation of the Descending Branch of the Left Coronary Artery in the Region of its Origin at the Bifurcation

Dog	EKG Changes			Remarks
	Days of ligation	5 days after ligation	After 40 days	
Bat	T − (1, V_6), QRS shortened, S−T + (1, V_6), polymorphic extra systoles, pulsus alternans	T + Q (3) vanished, lowered voltage, paroxysmal tachycardia, extrasystoles	T − (1), Q vanished (3), P−Q prolonged	T normal +
Gek	T + (1, 2, 3), diminished voltage (V_6, V_1)	T increased (V_6, V_1), S−T + (V_6, V_1)	T diminished, S−T + (V_6, V_1), P−Q prolonged	T normal − (2, 3) and + + V_6, V)
Chuk	T enlarged (2, V_1), S−T + (V_1). Polymorphic extrasystoles, pulsus alternans	T diminished, P−Q enlarged voltage lowered	T−(2), P vanished (3) Q−T diminished, lowered voltage, atrioventricular block	T normal +

Thus, it can be seen that changes, following ligation of the descending branch of the left coronary artery in its lower third, in so far as the blood pressure is concerned seem to be of very short duration. This indicates rapid compensation of the myocardial disturbance caused by the myocardial ischemia. The rise of the blood pressure on the day of surgery must be related to the reconstruction of the hemodynamics necessitated by the pneumothorax which, as has been shown experimentally [1, 3], is accompanied by sharp rises in blood pressure, and also related to a compensatory blood pressure rise observed to occur as a result of myocardial ischemia [2]. In cases when this reaction did not occur postoperatively (Lisa, Zhelty), there took place a severe fall in blood pressures later which, in all probability, was associated with weak compensatory mechanisms in these animals. The bradycardia observed in the acute ischemic phase must be regarded as a consequence of the increased tone on the part of the recurrent nerves because of the rise in the strength of the impulses emanating from the receptors in the vicinity of the infarcted myocardium and the adjacent pleura.

The clearest and most constant indicators of the instability and insufficiency of the coronary circulation resulting from the ligation are seen on the EKG. The changes and evolution of the T wave and S–T segment are characteristic of infarcts of the anterior wall of the left ventricle. As a rule, this ischemia activates the secondary automatic centers and this manifests itself as concordant extrasystoles (Fig. 1).

However, the circulatory changes produced by ligation of the descending branch of the left coronary at the juncture of the middle and lower thirds of the artery are rapidly compensated by the collateral circulation which, along with the data on the functional state of the cardiovascular system, confirms also the autopsy data which fails to reveal any wide-spread necrotic alterations in the myocardium.

b) EKG changes and hemodynamic alterations produced by ligating the descending branch of the left coronary artery near its origin at the bifurcation.

Ligation of the descending branch of the left coronary artery near its origin at the bifurcation produces the EKG pattern characteristic for an anterior wall infarct: inversion of T, S–T segment elevation, sensitivity alterations typical for this localization of the infarct and leading to characteristic EKG evolution (Table 2). With the higher ligation of the descending branch, the hypotensive swing from the maximal blood pressure was more pronounced so that, even on the day of ligation, there was noted a marked fall in blood pressure. Thus in dog Chuk the maximal blood pressure fluctuated normally between 108-126 mm mercury, while, after ligation, it fell to 84 mm and for five postoperative days did not exceed 88 mm. In all the experiments of this series there developed a tachycardia relative to the normal base. Dog Gek before surgery had a pulse of 66-95 per minute, while after the ligation the rate varied from 96 to 114 per minute, the similar data for Chuk being a rise from a pulse of 108 up to 180. Over the entire period of observation following the ligation there was also noted a rise in the circulation rate (Table 3).

TABLE 3

Changes in Blood Velocity After Ligation of the Descending Branch of the Left Coronary Artery

Dog	Blood velocity (in seconds)	
	Normal	After applying ligature
Chuk	11.5–12.6	8.5– 9.1
Gek	11.0–12.0	9.0–11.2

These marked alterations in cardiac contractions and blood velocities bespeak a mobilization of the compensating mechanisms existing in the cardiovascular system.

The gross and microscopic evidence of the results of the autopsies performed on the sacrificed animals confirms the presence of extensive anterior apical infarcts (Fig. 2).

However, it must be noted that pronounced insufficiencies of the cardiovascular system did not develop even when the descending branch of the left coronary artery was ligated near the bifurcation.

In order to clarify the role played by the recurrent branch of the vagus in the developing complex of changes, we conducted a series of experiments in which atropine was employed. Injecting atropine into dogs regularly having extrasystoles led, as a rule, either to abolition of these extrasystoles altogether or else to a

Fig. 2. Manifestations of scarring near the tip of heart in the ischemic zone. Inner surface of left ventricle (dog Chuk).

marked diminution in their number (Fig. 3). However, in these instances of rhythm normalization there were, sometimes observed marked EKG abnormalities. Our findings indicate that activization of foci of heterotopic excitation is associated with influences transmitted by the recurrent nerves. This coincides with the results

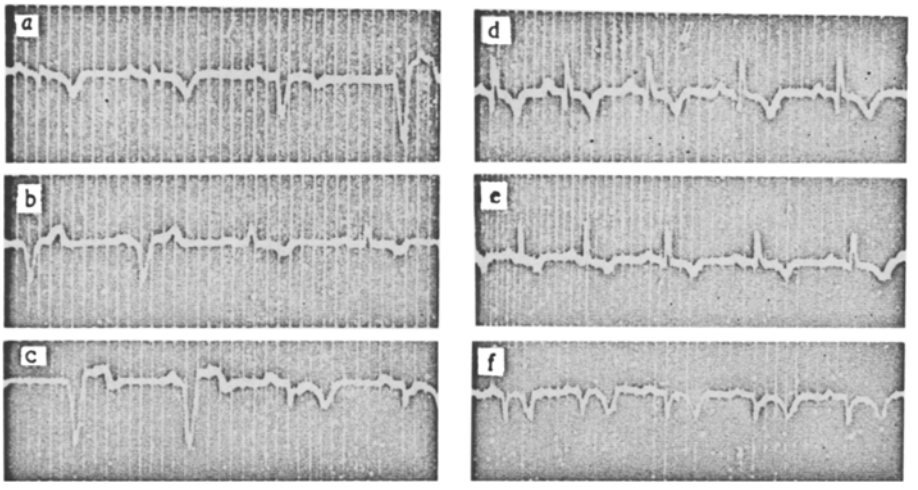

Fig. 3. The influence of atropine upon the rhythmic acitivy of the heart. I) EKG before atropine, a—lead II, b—lead III, c—V_6; II) EKG 15 minutes after internal administration of atropine (labeled as in Fig. I).

obtained by A. I. Smirnov and A. I. Shumilova [5] who demonstrated that either section of the recurrent nerves or the use of atropine eliminated extrasystoles present when experimental myocardial infarcts were produced. The absence of undesirable hemodynamic changes in the course of excluding pharmacologically the recurrent nerve gives us the possibility of recommending atropine as a drug to be employed when extrasystoles develop clinically as a result of myocardial infarction.

SUMMARY

Dogs were used to create infarcts of the anterior myocardial wall. The descending branch of the left coronary artery was ligated either near its origin or else at juncture of middle and distal thirds. The animals were observed for 40 days postoperatively and then sacrificed for complete cardiac studies. The EKG, the B.P. and heart rate were taken throughout this experimental series.

Atropine was used to abolish extrasystoles. The hemodynamic alterations were transient while the EKG ran the course usual for this type of infarct.

It is suggested that the recurrent nerve mediates heterotopic foci of cardiac excitation.

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