phates in their muscles is significantly higher than normal [7]. In the present experiments no significant difference was found between the levels of ATP and other free nucleotides in the muscles of adrenalectomized animals kept at room temperature [5] and exposed to cold for 4 h. On the contrary, the creatine phosphate concentration was significantly reduced.

The results described above thus point to the active participation of the adrenals in the regulation of energy metabolism during adaptation to cold.

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CHANGES IN GLYCOGENOLYSIS IN THE ZONE OF ISCHEMIA IN EXPERIMENTAL MYOCARDIAL INFARCTION

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During the first minutes after occlusion of the coronary artery in dogs, increased glycogenolysis was detected, for which activation of phosphorylase, phosphofructokinase, triose phosphate isomerase, and lactate dehydrogenase was responsible; aldolase and glyceraldehyde-3-phosphate dehydrogenase reactions became the stages limiting the rate of glycogenolysis. Activation of glycogenolysis was evidently due to the combined action of hypoxia and catecholamines.

KEY WORDS: experimental myocardial infarction; glycogenolysis.

During the study of early changes in glycogenolysis in the heart in experimental myocardial infarction as a rule activity of enzymes isolated from the tissue under optimal conditions has been studied [6], although this could not reveal changes taking place *in vivo*. In some investigations [2, 8, 13] a more adequate method based on measurement of the concentration of metabolites present in the tissue *in vivo* has been used, although even in these studies cardiac arrest has been produced by the use of a cardioplegic solution [8], the aorta has been detached [2], or anoxia has been present [13].

The object of this investigation was to study the dynamics of changes in the concentration of all metabolites of glycogenolysis in the zone of ischemia in experimental myocardial infarction and to evaluate changes in the activity of the corresponding enzymes from the ratio between the acting masses [11], in the zone of ischemia in experimental myocardial infarction.

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TABLE 1. Concentrations of Metabolites of Glycogenolysis in Zone of Ischemia in Dog's Heart at Various Times after Occlusion of Coronary Artery, μmoles/g Wet Weight of Tissue (M±m)

Time after occlusion of coronary artery, min	GLY	G1P	G6P	F6P	FDP	DHAP	GLA3P	3PGL	2PGL	PEP	PYR
0	23,44±1,43	0,029±0,001	0,20±0,01	0,055±0,005	0,030±0,002	0,037±0,005	0,007±0,001	0,062±0,007	0,013±0,002	0,015±0,001	0,085±0,012
2	17,08±1,10*	0,062±0,004*	0,40±0,03*	0,094±0,007*	0,100±0,008*	0,040±0,004	0,021±0,002*	0,066±0,008	0,013±0,004	0,014±0,001	0,080±0,009
5	10,24±1,06*	0,084±0,006*	0,50±0,04*	0,143±0,014*	0,135±0,008*	0,050±0,004	0,027±0,002*	0,074±0,008	0,015±0,002	0,014±0,001	0,067±0,008
30	5,05±0,54*	0,121±0,011*	0,64±0,09*	0,190±0,020*	0,166±0,022*	0,050±0,004	0,36±0,004*	0,073±0,007	0,014±0,002	0,013±0,001	0,057±0,006
60	5,76±0,80*	0,155±0,01 .*	0,61±0,07*	0,221±0,035*	0,173±0,015*	0,048±0,004	0,040±0,006*	0,071±0,10	0,015±0,002	0,013±0,001	0,058±0,009

Time after occlusion of coronary artery, min	LAC	ATP	ADP	P_{in}	PP	TPI	PGM	PPH	PK	LDH	GLA3PDH + PGK
0	2,32±0,22	6,22±0,33	0,56±0,05	2,38±0,18	4,91±0,43	0,20±0,03	0,21±0,02	1,4±0,2	62±9	31,7±5,6	10,2±0,6
2	4,44±0,46*	5,15±0,46	0,78±0,08*	3,60±0,42*	2,77±0,44*	0,54±0,07*	0,22±0,02	1,3±0,2	44±9	65,5±12,0*	3,45±0,39*
5	6,44±0,56*	4,27±0,36	0,87±0,07*	4,89±0,52*	1,36±0,29*	0,57±0,05*	0,20±0,01	1,0±0,2	27±4*	113,6±16,5*	2,76±0,24*
30	14,62±1,24*	2,54±0,35*	0,78±0,09*	9,36±0,90*	0,50±0,11*	0,73±0,04*	0,21±0,01	1,0±0,2	18±4*	290,7±45,0*	2,08±0,20*
60	11,80±1,90*	2,14±0,37	0,73±0,10*	10,99±1,29*	0,37±0,10*	0,84±0,10*	0,21±0,02	1,1±0,2	14±3*	268,5±76,7*	1,93±0,25*

Legend. Here and in Table 2, values whose changes are significant compared with the initial level ($P<0.05$) are indicated by an asterisk.

TABLE 2. Ratio of Acting Masses in Reactions of Glycogenolysis in Zone of Ischemia in Dogs' Hearts at Different Times after Occlusion of Coronary Artery (M±m)

Time after occlusion of coronary artery, min	Pase	PGM	PGI	PFK	ALD
0	0,00124±0,00025	7,4±0,7	0,29±0,02	0,055±0,007	0,010±0,003
2	0,0041±0,0004*	6,4±0,2	0,24±0,02	0,188±0,030*	0,009±0,002
5	0,0087±0,0012*	6,3±0,3	0,28±0,02	0,213±0,031*	0,011±0,002
30	0,0240±0,003*	5,4±0,3*	0,30±0,03	0,398±0,091*	0,011±0,002
60	0,0270±0,006*	4,0±0,3*	0,38±0,06	0,229±0,041*	0,013±0,003

EXPERIMENTAL METHOD

Experiments were carried out on 10 mongrel dogs of both sexes weighing 9-18 kg. Myocardial infarction was induced in the thoracotomized dogs, under pentobarbital anesthesia (40 mg/kg), by ligation of the descending branch of the left coronary artery 1 cm from the auricle. Samples from the zone of ischemia were taken at the time of ligation (0 min) and 2, 5, 30, and 60 min after occlusion of the coronary artery. Samples weighing 200-300 mg were taken with special forceps [14], ensuring instantaneous freezing of the tissue at the temperature of liquid nitrogen. The concentrations of the various metabolites were determined as follows: glycogen (GLY) by the method in [7], glucose-1-phosphate (G1P), glucose-6-phosphate (G6P), fructose-6-phosphate (F6P), fructose-1,6-diphosphate (FDP), dihydroxyacetone phosphate (DHAP), glyceraldehyde-3-phosphate (GLA3P), 3-phosphoglycerate (3PGL), 2-phosphoglycerate (2PGL), phosphoenolpyruvate (PEP), pyruvate (PYR), lactate (LAC), ATP, and ADP by enzymic methods [5], and inorganic phosphate (P_{in}) by the method in [1]. Activity of phosphorylase (Pase), phosphoglucomutase (PGM), phosphoglycoisomerase (PGI), phosphofructokinase (PFK), aldolase (ALD), triose phosphate isomerase (TPI), and total glyceraldehyde-3-phosphate dehydrogenase and phosphoglycerate kinase activity (GLA3PDH + PGK), phosphoglycerate mutase (PGM), phosphopyruvate hydrolase (PPH), pyruvate kinase (PK), and lactate dehydrogenase (LDH) were estimated from the ratio between the acting masses, i.e., the ratio between the concentrations of reaction products and the concentrations of substrates [11].

EXPERIMENTAL RESULTS

After occlusion of the coronary artery the concentrations of GLY and ATP decreased, those of G1P, G6P, FDP, GLA3P, LAC, ADP, and P_{in} increased, the phosphate potential (PP; $ATP/ADP \cdot P_{in}$) fell, and there was no significant change in the concentrations of DHAP, 3PGL, 2PGL, PEP, and PYR (Table 1). The rates of changes in concentrations of the metabolites were greatest during the first 5 min, i.e., at the time of greatest decrease in pO_2 [4], after which it diminished considerably. By the 30th minute the concentration of most metabolites had reached the steady state. The ratio between acting masses rose successively for Pase, PFK, TPI, and LDH, it decreased for PGM and PK, and was virtually unchanged for PGI, ALD, PGM, and PPH (Table 2).

Activation of Pase and PFK after occlusion of the coronary artery may be due to a decrease in the ATP concentration and an increase in the concentrations of ADP, AMP, and P_{in} in the zone of ischemia, i.e., to a shift to the right in the ATP—ADP—AMP—P_{in} system. The decisive role in the activation of these enzymes in the first minutes of ischemia evidently belongs to P_{in} [2]. Catecholamines liberated from the focus of ischemia [10], by their action on adenyl cyclase, also cause an increase in the concentration of cyclic AMP, an activator of Pase and PFK [9]. A contribution to activation of the LDH reaction in the direction of conversion of PYR into LAC is made by an increase in the NADH/NAD ratio in the zone of ischemia, which was demonstrated in [3]. Among the factors limiting the rate of glycogenolysis in the zone of ischemia are a decrease in the NAD concentration, necessary for the GLA3PDH reaction, and acidification of the medium, leading to inhibition of GLA3PDH and PFK [12].

As Fig. 1 shows, the considerable increase in the rate of the Pase and PFK reactions was not accompanied by an adequate increase in the rate of the ALD and GLA3PDH reactions, which became the stages of limiting the reaction velocity. This was shown by the sharp increase in concentration of substrates of the FDP and GLA3P reactions and by the fact that, despite a significant increase in the intermediate metabolites from G1P to GLA3P, the changes

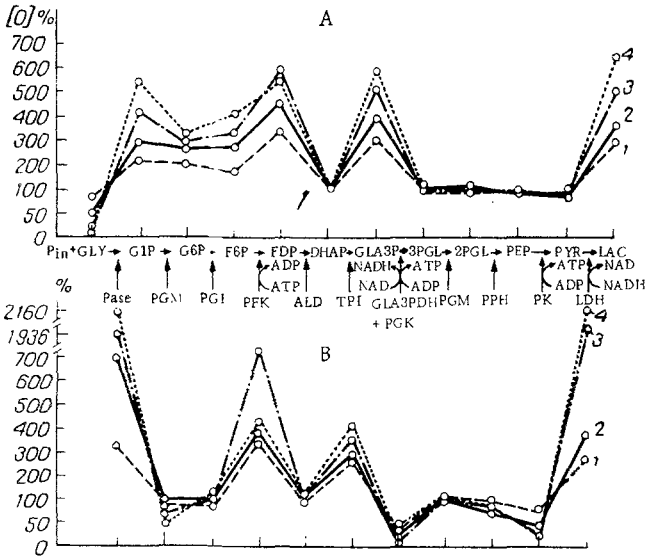

Fig. 1. Successive changes in concentrations of metabolites (A) and ratio of acting masses — RAM (B) in reactions of glycogenolysis in zone of ischemia 2 min (1), 5 min (2), 30 min (3), and 60 min (4) after ligation of coronary artery. Abscissa: A) metabolites; B) enzymes of glycogenolysis arranged in their natural order (indicated by the scheme in the center of diagram); ordinate, changes in concentrations of metabolites and RAM (values at time of ligation — 0 min — taken as 100%).

from 3PGL to PYR were not significant. The presence of limiting stages and the decrease in the velocity of the PK reaction lead to disparity between ATP formation in the course of glycogenolysis and the degree of intensification of GLY breakdown.

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