EFFECT OF THE DEGREE OF MYOCARDIAL HYPERTROPHY ASSOCIATED WITH AN EXPERIMENTAL HEART DEFECT ON THE RESISTANCE TO ALTITUDE HYPOXIA

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Hypertrophy of the myocardium associated with compensatory hyperfunction of the heart caused by a structural defect or with hypertension has been the subject of extensive experimental research [1, 3, 5, 8-13], yet insufficient attention has been paid to the study of the extent to which the degree of myocardial hypertrophy affects the resistance of the body to efforts making excessive demands on the cardiovascular system. In particular, there is no information in the literature on the relationship between the resistance of the body to anoxic anoxia and the degree of development of hypertrophy of the heart.

We have studied the effect of different degrees of hypertrophy of the myocardium on the resistance of the cardiac activity and the body as a whole to progressive altitude hypoxia.

EXPERIMENTAL METHOD

Experiments were conducted on 28 male albino rats of the same age, weighing 200-220 g; 10 rats were control, while in the other 18 experimental coarctation of the aorta was produced in the subphrenic division, using the techniques of Beznak [8] and A. Kh. Kogan [3], the lumen of the aorta being constricted to approximately one-third its original area. Four months after the production of coarctation the animals were placed in turn in a pressure chamber and "raised" at a constant velocity of 2 km/min. After each 1 km of the "ascent" a halt of 10-15 sec was made, during which the ECG was recorded in standard leads and the pneumograms of the animal at that "altitude" were traced. The "ascent" continued to the highest "altitude" tolerated, i.e., until respiration ceased and an agonal convulsion developed. Because of the fact that this end-point was protracted in time and because of the considerable velocity of the "ascent," the "ceiling altitude" was taken to be the 1 km interval of "altitude" between the halts during which the terminal state appeared. After removal of the animal from the pressure chamber, the relative weight of the heart was determined and the heart was examined histologically.

EXPERIMENTAL RESULTS

Myocardial hypertrophy was established in all the animals with coarctation of the aorta. However, although the aorta was constricted to the same degree, the degree of hypertrophy of the myocardium varied from one animal to another: compared with the normal average relative weight of the heart of 0.0029, in the experimental animals it varied from 0.0033 to 0.0069. Depending on the degree of myocardial hypertrophy, the animals were subdivided into a group with moderate hypertrophy (relative weight of the heart less than 0.0040 – 7 animals) and a group with considerable hypertrophy (relative weight of the heart more than 0.0040 – 11 animals).

It is clear from the table that moderate hypertrophy had no significant effect on the resistance of the animal to acute "altitude" hypoxia, but considerable hypertrophy with a relative weight of the heart of 0.0041 and more caused a marked decrease in the normal resistance: whereas the zone of onset of death of the control rats and the rats with moderate hypertrophy of the heart lay in the "altitude" interval from 11 to 13 km, for the animals with considerable hypertrophy it was lowered to the "altitude" interval between 7 and 10 km. The correlation between the relative weight of the heart and the "ceiling altitude" of the animals for the groups with a relative weight of the heart of less than 0.0040 and more than 0.0040 was statistically significant.

Resistance of Animals to Progressive "Altitude" Hypoxia

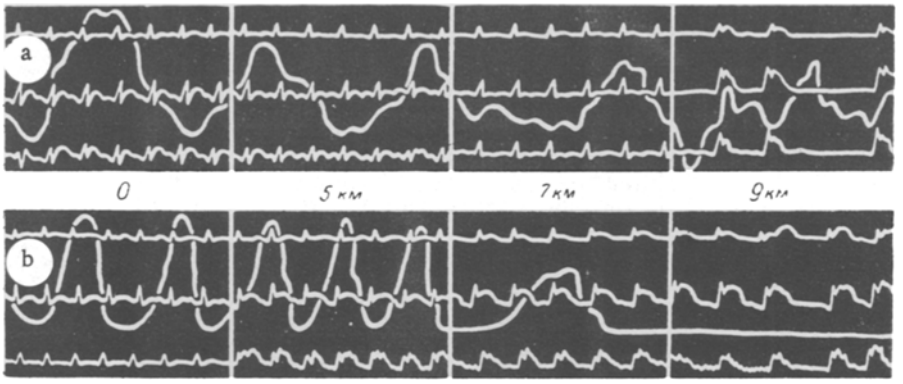
Control		Animals with moderate cardiac hypertrophy		Animals with considerable cardiac hypertrophy	
relative wt. of the heart	"ceiling altitude" (in km)	relative wt. of the heart	"ceiling altitude" (in km)	relative wt. of the heart	"ceiling altitude" (in km)
0,0027	11—12	0,0033	11—12	0,0041	7—8
0,0028	11—12	0,0036	11—12	0,0041	9—10
0,0029	11—12	0,0036	11—12	0,0047	7—8
0,0029	11—12	0,0037	12—13	0,0047	8—9
0,0029	12—13	0,0038	11—12	0,0047	9—10
0,0029	12—13	0,0038	11—12	0,0048	8—9
0,0030	11—12	0,0039	11—12	0 0048	7—8
0,0030	11—12			0,0049	7—8
0,0031	11—12			0,0056	9—10
0,0031	11—12			0,0060	7—8
				0,0069	8—9
Average 0.0029	11—12	0,0037	11—12	0,0048	8—9

The changes in the ECG of the animals during their "ascent" also varied from animal to animal, but the most constant feature in the great majority of the rats consisted of changes in the S – T segment and the T wave. The changes in these elements of the cardiogram were clearly related to the progressive lowering of the barometric pressure and were periodic in character. In the animals with moderate myocardial hypertrophy they were similar to the findings in the control animals, and took the form of a gradual lowering of the S – T segment and a reduction of the voltage of the T wave during the "ascent" from 5 to 8 km. In the first phase of the changes the T wave always remained positive. At an "altitude" of 8-9 km the direction of the changes in the S – T segment and the T wave altered sharply, and they began to rise steeply to a maximum at the moment of clinical death, The second phase of the displacement of the S – T segment upward from the isoelectric axis and the increase in the T wave usually took place against a slowing of the rhythm and atrioventricular block, and progressed into ventricular fibrillation. The cardiographic changes in the animals with considerable myocardial hypertrophy followed a different pattern: the phase of lowering of the S – T segment and of the voltage of the T wave was absent or fleeting and ill defined, and the progressive upward displacement of the S – T segment from the isoelectric axis and enlargement of the T wave could be observed at an altitude of 5-7 km. At this relatively low "altitude" appeared signs of heart block, of atrioventricular rhythm, and of deformation of the waves of the QRS complex, changing into ventricular fibrillation (see figure).

Morphological investigation of the heart of the experimental animals, using a histotopographic method, revealed marked thickening of the myocardial fibers associated with focal sclerotic changes, mainly in the left ventricle. In the group of animals with considerable hypertrophy of the heart the signs of cardiosclerosis were more generalized and more severe in character than in the animals with moderate hypertrophy.

The great difference in the degree of development of myocardial hypertrophy in the various animals (although the degree of constriction of the aorta was the same) indicates that different degrees of myocardial hypertrophy may develop in response to equal loads. The fact that hyperfunction and hypertrophy of the heart are not parallel in trend has been mentioned more than once previously [2, 7]. These facts support the view [8] that, besides hyperfunction of the heart, the degree of hypertrophy of the organ is also largely dependent on the state of the neuro-endocrine regulatory mechanisms of the body.

The fact discovered in our experiments – the lowering of the resistance of animals with considerable myocardial hypertrophy to progressive "altitude" hypoxia – suggests that the degree of hypertrophy of the heart is an important factor limiting the resistance of the organism to acute hypoxic hypoxia. The pattern of the cardiographic changes in animals with considerable hypertrophy of the myocardium indicates that the lowering of the resistance to hypoxia is related to a lowering of the functional resistance of the heart. The fact that the considerably hypertrophied heart is functionally inefficient is in accordance with the findings [9] showing that the degree of tolerance to maximal physical effort falls as the degree of hypertrophy increases. Modern ideas of the structural biochemical changes in the considerably hypertrophied myocardium explain the decrease in its functional resistance to acute hypoxia by at least two



ECG in standard leads and pneumogram of a rat with a relative weight of the heart of 0.0037 (a) and in a rat with a relative weight of the heart of 0.0047 (b) at "altitudes" of 0, 5, 7, and 9 km. Downward displacement of S – T segment and decrease in size of T wave at an "altitude" of 5-7 km in the rat with moderate hypertrophy of the heart. Upward displacement of the S – T segment and enlargement of the T wave at the same "altitude" in the rat with considerable hypertrophy of the heart.

factors: 1) a reduction of the "concentration" of capillaries in the myocardium, leading to an increase in the distance to be traversed by oxygen and nutrient substances from the capillary to the center of the muscle fiber [14, 15]; and 2) by a disturbance in the structure and a reduction in the mass of the mitochondria, discovered by Wollenberger [4], resulting in a high intensity of oxidative energy-producing processes in the myocardium even in a state of rest, and consequently, in the high sensitivity of the myocardium both to overloading and to hypoxia, such as existed in our experimental conditions.

SUMMARY

Experimental coarctation of the abdominal aorta with constriction of its lumen to one-third of the original diameter was created in 18 albino rats. Four months later various degrees of myocardial hypertrophy developed in the animals with a relative weight of the heart ranging from 0.0033 to 0.0069. In "elevation" in the barochamber, the "altitude ceiling" of the animals with a relative cardiac weight below 0.0040, did not differ from the normal one. The "altitude ceiling" proved to be considerably decreased in animals with a relative cardiac weight of over 0.0040. Analysis of ECG recorded during the "elevation" demonstrated that in the animals with a considerable myocardial hypertrophy reduced resistance to the acute "high altitude hypoxia" depended on the reduction of the functional resistance of the heart.

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