CONNECTIVE-TISSUE COMPONENT OF THE MYOCARDIUM IN THE EMERGENCY STAGE OF COMPENSATORY HYPERFUNCTION OF THE HEART

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The reaction of the connective-tissue component of the left ventricular myocardium of rats to hypertrophy induced by coarctation of the abdominal aorta in the subdiaphragmatic portion was investigated by electron microscopy in conjunction with morphometric analysis. The animals were killed 1, 5, and 10 days after the operation. The relative volume of connective tissue in the heart of intact animals was 10.2%, of which 2.0% was accounted for by cells, 0.2% by fibers, and 8% by the structureless part of the ground substance. In the emergency stage of hypertrophy an increase was observed in the total volume of connective tissue; depending on the time, the ratio between the various components changed. Activation of synthesis also took place in cells of the fibroblast series.

KEY WORDS: connective tissue; heart; emergency stage of compensatory hyperfunction.

Connective-tissue structures play an important role in the maintenance of metabolism of the cardiomyocytes, being responsible for the transport of metabolites between the blood stream and muscle cells; the velocity of transport and the type of materials transported may depend on the character of the ground substance of the connective tissue. The ionic composition of the surrounding microenvironment is an important factor ensuring correct activity of the cardiomyocytes [9]. This microenvironment also is created by the interstitial connective tissue [3, 7]. Structures of the connective tissue which constitute the supporting framework of the organ may determine the degree of resistance of the heart wall to the blood flow and, naturally, the degree of its extensibility, an important factor for the volume of work done [10, 11]. Accordingly, in order to understand the pattern of functional morphology of the myocardium it is important to have detailed knowledge of the state of each of its elements in the intact heart and in the organ after experimental procedures or in pathology. The ways in which such investigation can be pursued were noted in a previous publication [6].

The object of this investigation was to study qualitative and quantitative indices of the connective-tissue component of the left ventricle of rats with a normal and a hypertrophied heart.

EXPERIMENTAL METHOD

Experiments were carried out on 20 male August rats weighing 150 g. Coarctation of the abdominal aorta was carried out under pentobarbital anesthesia (0.05 mg/g body weight). Constriction of the aorta was carried out by the method described previously [8]. The diameter of the tube was 0.71 mm. The animals were killed 1, 5, and 10 days after the operation, corresponding to the emergency stage of compensatory hyperfunction of the heart [4]. Material taken from five intact animals served as the control. The hearts of the control and experimental rats were weighed before processing. Five samples were chosen from the wall of the left ventricle, fixed by Karnovsky's method [1], and postfixed with OsO_4. The samples were embedded in Epon-812. Sections from each block, 50 nm thick, were studied in the Hitachi-11E-2 electron microscope. Morphometric data were obtained by the point method, using stereologic principles [2]. Quantitative characteristics of the connective-tissue structures of the myocardium — the relative volume of cells, fibers, and ground substance — were studied under a magnification of 5300. At each point at least 50 fields of vision, with a total area

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TABLE 1. Ratios between Volumes (in %) of Different Components of Myocardial Connective Tissue in Emergency State of Compensatory Hyperfunction of the Heart (M±m)

Component	Control	Time after operation, days		
		1	5	10
Cells	2,0±0,04	2,75±0,04	2,3±0,04	2,1±0,07
P		<0,001	<0,001	<0,01
Fibers	0,2±0,01	0,3±0,01	0,9±0,03	0,4±0,01
P		<0,001	<0,001	<0,001
Ground substance	8,0±0,09	7,7±0,09	12,3±0,1	12,4±0,09
P		<0,001	<0,001	<0,001

TABLE 2. Changes in Volume of Granular Endoplasmic Reticulum of Fibroblasts in Emergency Stage of Compensatory Hyperfunction of the Heart

% of all cells	Control	1 day	5 days	10 days
GER	4,25±0,10	5,37±0,10	5,58±0,20	6,51±0,21
P		<0,001	<0,001	<0,001

of 5000 μ^2, were examined. Among the connective-tissue cells mature fibroblasts were counted under a magnification of 16,000, with at least 20 cells per point. Maturity of the fibroblasts was judged on the basis of the state of the sarcoplasmic reticulum and Golgi complex [5]. All parameters tested were compared by Student's criterion.

EXPERIMENTAL RESULTS

Electron-micrographs obtained 24 h after coarctation of the aorta revealed dilated vessels of papillary type, packed with blood cells. The endothelium of the capillaries was thinner than normal. The pinocytotic activity of some endothelial cells was increased and a tendency was observed for changes in the cell organelles, with the appearance of an increased number of ribosomes and widening of the cisterus of the cytoplasmic reticulum. Changes took place in the interstitial connective tissue; its relative volume increased a little, the relative volume of its cells increased by 3%, and the volume of the fibrous part of the ground substance by 50% (Tables 1 and 2). At the same time an increase was observed in the synthetic activity of cells of the fibroblast series. This was shown by an increase in the volume occupied in the mature fibroblasts by the granular endoplasmic reticulum.

An increase in the weight of the heart by 19% compared with the control was found 5 days after the operation and subsequently. Changes in the blood vessels continued in the same direction as before. The relative volume of the ground substance of the connective tissue increased sharply on account of an increase in its fibrous (by 4.5 times) and structureless (by 1.5 times) parts. As regards the relative volume of the cells, this fell a little, although it still remained higher than the control (Table 1). At the same time there were changes in the qualitative composition of the connective-tissue cells. Numerous activated macrophages appeared among them. The synthetic activity of the mature fibroblasts continued to increase.

The relative volume of the whole connective tissue of the left ventricle was reduced 10 days after coarctation of the aorta, with a simultaneous decrease in the volume occupied by fibrous components of the ground substance, although the tendency for the relative percentage volume of its structureless part to increase still remained. The capillaries remained dilated and congested with blood. In some of the endotheliocytes the number of elements of the granular cytoplasmic reticulum increased considerably, the lamellar complex was clearly defined, many free ribosomes, polysomes, and inclusions were present, and pinocytotic activity remained high as before. The mosaic reaction of the capillary endothelium was very pronounced: Side by side with an active endotheliocyte there were cells with a

thin, pale cytoplasm, containing few organelles, and with single pinocytotic vesicles. Attention was also drawn to the oriented nature of the changes in cells of the fibroblast series.

During the study of the emergency stage of compensatory hyperfunction of the heart, transformations were observed in vessels of exchange type and in connective-tissue structures. Changes in the structure of the interstitial tissue were probably due to its participation in the formation of adaptive reaction and to the need for a change in the level of transport of metabolites, in the character of the substances transported, and to correction of the composition of the microenvironment of the myocytes. This aspect of the problem may serve as the basis for further investigation of the role of the connective tissue of the heart.

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MORPHOLOGICAL AND FUNCTIONAL FEATURES OF THE LEFT VENTRICLE IN RABBITS WITH EXPERIMENTAL ALCOHOLIC CARDIOMYOPATHY

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Against the background of chronic alcohol poisoning in rabbits a sharp decline is observed in the contractile power of the left ventricle, accompanied by a significant lengthening of the phases of isometric contraction and isometric relaxation. Morphological investigation of the heart revealed marked hypertrophy of the myocardium and intensification of intramyocardial lipolysis, leading to accumulation of acid lipids in the heart muscle. It may be that these lipids, requiring additional quantities of oxygen for their utilization, lead to the appearance of a state of relative hypoxia in the myocardium. Combined with the deficiency of diastole, this may lead to weakening of the contractile power of the heart and to the compensatory development of hypertrophy of the myocardium.

KEY WORDS: cardiomyopathy; alcohol; heart; bioenergetics; lipids.

The mechanisms of development of alcoholic cardiopathy have not yet been adequately explained [1, 2], although this disease is very widespread and accounts for a high percentage

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