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ULTRASTRUCTURAL CHANGES IN CARDIOMYOCYTES AND CAPILLARIES OF HEART MUSCLE AFTER VAGOTOMY AND PHYSICAL EXERCISE

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KEY WORDS: physical exercise, left-sided vagotomy; cardiomyocytes; blood capillaries.

The trophic role of the vagus nerve and its role in the pathogenesis of myocardial dystrophies are among the most important problems in medicine. Numerous investigations [1, 3, 9, 11, 13] have shown that blocking extracardial parasympathetic nervous influences on the heart is accompanied by a disturbance of the tissue catecholamine balance, by changes in some metabolic processes, and by profound morphologic disturbances. The attention of research workers has been drawn particularly to adaptation of the heart during physical exercise and the trophic role of the vagus nerve and its role in the maintenance of myocardial function [2, 4, 5, 10, 12].

In the investigation described below an ultrastructural study of the cardiomyocytes and capillaries of heart muscle was undertaken after extracardial parasympathectomy and measured physical exercise.

EXPERIMENTAL METHOD

Experiments were carried out on 30 adult male noninbred albino rats weighing 200-225 g. The animals were divided into three groups: 1) control, 2) rats made to carry out measured physical exercise (submaximal and maximal), 3) animals subjected to partial surgical left-sided parasympathetic denervation and subsequently doing measured physical exercise. The tests were carried out on the 5th, 7th, and 14th days. Left-sided vagotomy in the lower third of the neck was performed under sterile conditions and ether anesthesia. Animals of groups 2 and 3 did physical exericse twice on an electric treadmill for 30 min with an interval of 24 h. A speed of 20.9 m/min was chosen for submaximal exercise, 29.8 m/min for maximal. Immediately after measured physical exercise the animals were decapitated and the heart removed. Pieces of tissue from the left ventricle were minced in 1% OsO_4 solution in phosphate buffer, pH 7.4, and fixed for 2 h, and then dehydrated and embedded in Epon and Araldite. Sections 20-50 nm thick were cut on the Tesla BS-490A ultramicrotome and examined in the UÉMV-100V electron microscope.

EXPERIMENTAL RESULTS

An electron-microscopic study of the left ventricle of the animals of group 2 after submaximal physical exercise revealed trivial ultrastructural changes in the cardiomyocytes. Most of the myocardial muscle cells were virtually indistinguishable from the control. In some places, however, the cell nuclei were enlarged, the nuclear membrane showed numerous recess-like indentations, and the chromatin in the nucleoplasm was condensed into clumps. The nucleolus was displaced toward the periphery. In some cardiomyocytes the mitochondria were enlarged and their matrix translucent. Cisterns and tubules of the sarcoplasmic reticulum were dilated. The lamellar apparatus consisted of tiny vesicles and the regular orientation of the myofibrils was disturbed. The capillary endotheliocytes contained

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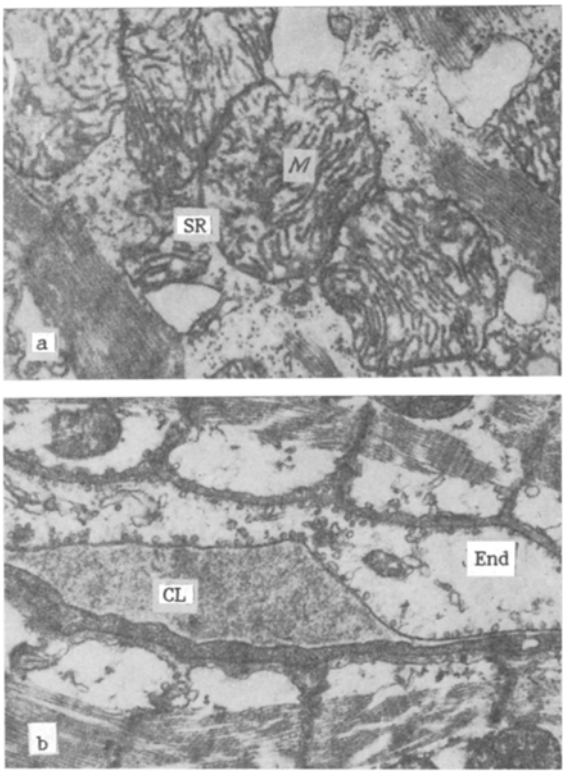

Fig. 1. Ultrastructural changes in cardiomyocytes (a) and capillaries (b) after maximal physical exercise. Dilated cisterns of sarcoplasmic reticulum (SR), swelling of mitochondira (M); edema of cytoplasm of endotheliocytes (End) of capillaries and narrowing of their lumen (CL). Magnification: a) 10,000, b) 7000 ×.

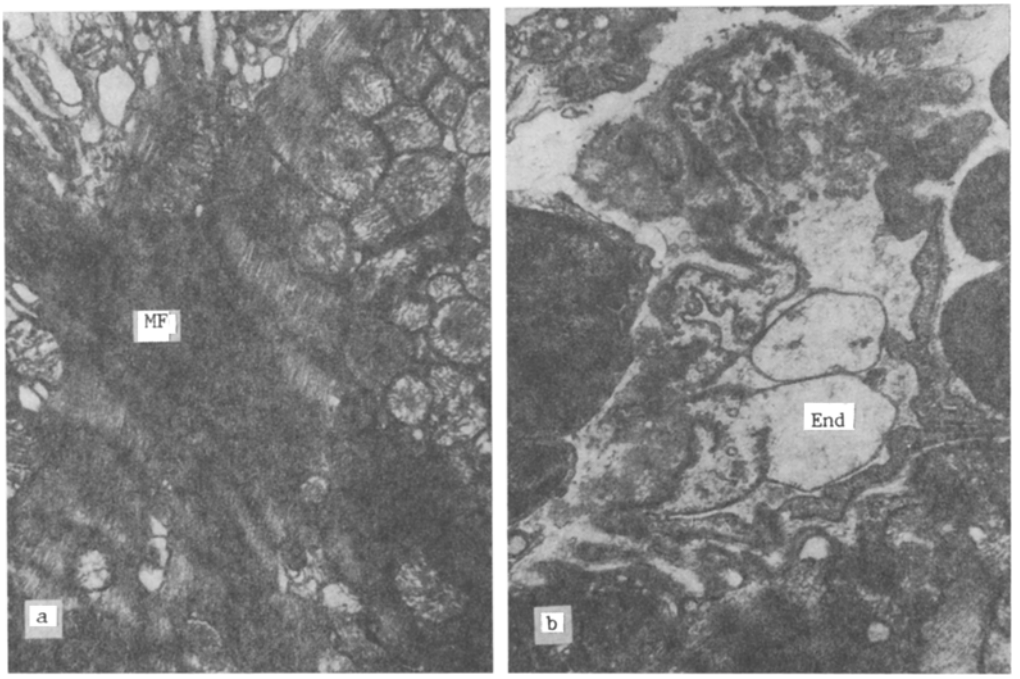

Fig. 2. State of cardiomyocytes (a) and capillaries (b) after partial parasmpathectomy and maximal physical exercise. Overcontraction of myofibrils (MF) of cardiomyocytes, marked edema of capillary endotheliocytes (End) with disturbance of integrity of luminal plasmalemma. 6000 ×.

many micropinocytotic vesicles. The inner plasmalemma formed evaginations into the capillary lumen, thus constricting it somewhat. The basement membrane was thickened in some places.

Maximal physical exercise by intact rats led to more marked ultrastructural changes in the cardiomyocytes and capillaries of the left ventricle. The nuclei were irregular in shape. Chromatin granules in the nucleoplasm were distributed as discrete clumps. Mitochondria in the perinuclear zone and along the myofibrils were enlarged, and in some places the sarcomere/mitochondrion ratio was abnormal. The cristae in some mitochondria were fragmented. The sarcoplasmic reticulum in the cardiomyocytes was considerably widened (Fig. 1a). Relaxation of the myofibrils was observed: the A and I disks and the Z bands were distinctly outlined. Swelling of the sarcoplasm in some parts led to unwinding of the myofibrils. Large vacuoles appeared along the sarcolemma of the cardiomyocytes. After maximal physical exercise the capillary lumen was greatly constricted as a result of marked edema of the endotheliocytes (Fig. 1b). It became slit-like in shape. The cytoplasm of the endotheliocytes had low electron density. The endotheliocyte nuclei were oval in shape, with translucent nucleoplasm, and the mitochondria were swollen. Profiles of the sarcoplasmic reticulum and lamellar apparatus were widened. Meanwhile endotheliocytes with electron-dense cytoplasm could be seen. The basement membrane was indistinct and homogeneous.

In rats doing exercise of submaximal power on the 7th day after vagotomy (group 3) translucency of the sarcoplasm could be seen in some muscle cells of the left ventricle. The nuclei in most cases were large, with hyaloplasm of low electron density and with an eccentric nucleolus. The nuclear membrane was overstretched. The perinuclear space was absent. In the phase of increased working capacity of the heart the mitochondria were swollen, with a homogeneous matrix and single cristae. Cisterns of the sarcoplasmic reticulum were dilated. Areas of alternation of contraction and relaxation of the myofibrils could be observed in the cardiomyocytes. Their typical cross-striation was disturbed. Endothelial cells in the capillaries were swollen and their lumen constricted. Later (14th day) after left-sided vagotomy submaximal exercise caused no marked changes in ultrastructure of the cardiomycoytes or capillaries.

Partial parasympathectomy and maximal physical exertion aggravated the degree of ultrastructural disturbances of the cardiomyocytes and capillaries of the left ventricle and caused marked destructive changes in some areas. Submicroscopic investigation of the cardiomyocytes of the left ventricle of the rats 7 days after vagotomy and maximal physical exercise revealed numerous zones of overcontraction of myofibrils (Fig. 2a). The nuclei of the muscle cells were enlarged and their chromatin was distributed marginally. Cisterns of the sarcoplasmic reticulum were dilated and their membranes overstretched and fragmented in some places. Many mitochrondria were enlarged and their matrix translucent. The internal structure of some mitochondria was disturbed, with the formation of empty vacuoles. Lipid granules, the number of which rose sharply during maximal physical exercise, were in close contact with the other membranes of the mitochondria. In some places the myofibrils showed destructive changes. Their protomyofibrils were thinner and more loosely arranged than normally. Meanwhile hyperplasia of intracellular structures was observed in individual cardiomyocytes [6, 7, 8].

The cytoplasm in the capillary endotheliocytes was osmiophobic and contained many medium-sized and large vacuoles. The inner plasmalemma formed hernia-like evaginations, with a decrease in thickness and disturbance of integrity of the membrane (Fig. 2b). The basement membrane was widened and deformed in some places.

The fine structure of the left ventricle of the rats was preserved after maximal physical exerise, done 14 days after left-sided vagotomy. Cardiomyocyte nuclei were large in size and the mitochondria in most cells, both in the perinuclear zone and along the myofibrils, were swollen, with a translucent matrix. Mitochondria with irregularly arranged cristae were frequently seen. The outer mitochrondrial membranes were in close contact with one another and with myofibrils. Tubules of the sarcoplasmic reticulum (L- and T-systems) in many myofibrils were considerably dilated, and the lumen was packed with contents with low electron density. The myofibrils characteristically contained regions of marked contractions and disturbances of cross-striation. The disks, zones, and lines were no longer distinctly outlined. Glycogen granules could not be seen in the cytoplasm of the cardiomyocytes. Cytoplasm of the endotheliocytes of the heart muscle in vagotomized rats doing maximal physical exericse was electron-dense. The internal plasmalemma frequently formed long microvilli, directly into the capillary lumen.

Submaximal physical exericse thus causes moderately severe dystrophic changes in the cardiomyocytes and capillaries of the left ventricle. Maximal physical exercise, especially when integrative nervous influences are disturbed, leads to the development of focal destructive changes in the myocardium.

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ULTRASTRUCTURE OF DISTRIBUTION SPHINCTERS AND PROCORTICAL ARTERIES IN THE PIAL ARTERIAL SYSTEM IN RABBITS

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KEY WORDS: microcirculation, distribution sphincters, precortical arteries, ultrastructure of arterial wall, neurogenic mechanism.

The local blood flow in the cerebral cortex can be changed independently in a small volume of tissue measuring about 0.5-1 mm^3 [3, 5, 9]. Analysis of control of the blood flow in the cerebral cortex has shown that it can take place on account of specific microvascular segments, or distribution sphincters of the pial artery and precortical arteries [2, 6, 10]. However, it was not known whether the walls of these microvessels have any distinguishing structural features responsible for the character of their function.

The aim of this investigation was to study, with the light and electron microscopes, the structure of the walls of the distribution sphincters and precortical arteries, which play an important role in the control of local blood flow in the cerebral cortex.

EXPERIMENTAL METHOD

Experiments were carried out on 19 adult rabbits weighing 2.5-3 kg anesthetized with urethane (1 g/kg, intravenously). The preliminary operations included tracheotomy,

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