CHANGES IN THE CAPILLARY ULTRASTRUCTURE OF THE RAT MYOCARDIUM FOLLOWING NONREPETITIVE PHYSICAL EXERTION

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The capillary ultrastructure of the myocardium of untrained male Wistar albino rats was studied during the period of fatigue after nonrepetitive physical exertion (swimming). Besides capillaries with the ordinary structure, many of them showed increased micropinocytosis and the appearance of numerous cytoplasmic projections on the luminal surface of the endothelium indicating increased endothelial permeability. In some cases considerable pericapillary edema was seen. The number of polysomes in the endothelium was increased. The results point to the possible morphological mechanisms of pathological changes in the heart.

KEY WORDS: pericapillary space; myocardium; physical exertion; micropinocytosis.

There have been few special investigations of changes in the ultrastructure of the myocardial capillaries during physical exertion. As a result of the action of physical exertion, for instance, pericapillary edema is observed [5] and mitoses are found in the endothelial cells and pericytes [10]. It was therefore decided to undertake the present investigation to remedy this deficiency.

EXPERIMENTAL

Male Wistar albino rats weighing 180-120 g, kept under standard conditions, were used. Nonrepetitive physical exertion of moderate intensity and submaximal duration consisted of swimming in water at 30°C carrying a weight amounting to 2-3% of the animal's body weight. The animals were killed by decapitation during the period of fatigue corresponding to swimming for 4 h. Areas of myocardium from the left ventricle and atrium were quickly placed in 1% osmium tetroxide solution in phosphate buffer. The material was dehydrated in increasing concentrations of acetone and embedded in a mixture of Epon 812 and Araldite. Ultrathin sections were stained with uranyl acetate and lead citrate.

RESULTS

During the period of fatigue several morphological changes constituting a part of the structural and functional changes in the heart during this period of physical exertion were discovered in the wall of the capillaries of the rat myocardium. Considerable widening of the pericapillary space, from 150-100 nm in a state of relative rest (control), was frequently observed (Fig. 1). Collagen fibrils, finely granular material of average electron density, and organelles of fragmented cells were found in this widened, edematous pericapillary space. In some cases solitary red blood cells also were present.

Occasionally numerous pinocytotic vesicles and cytoplasmic projections facing the lumen of the capillary were observed in the capillary endothelium. The pinocytotic vesicles 600-1000 Å in diameter were closely packed together. The number of pinocytotic vesicles in 1 μ^2 area of cytoplasm amounted to 180, whereas under normal conditions [10] the maximal concentration of pinocytotic microvesicles in the endothelium is 120/μ^2. Pinocytotic vesicles arranged in chains also were seen.

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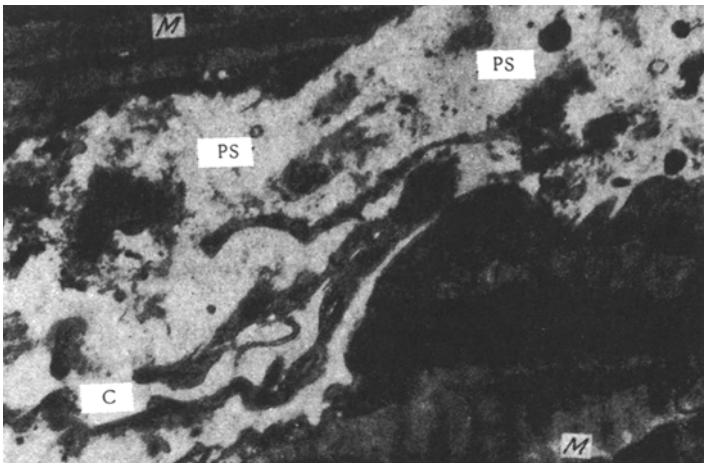

Fig. 1. Edema of pericapillary space in rat myocardium during fatigue after nonrepetitive physical exertion. C) capillary; PS) pericapillary space; M) myocardiocyte; 7000 ×.

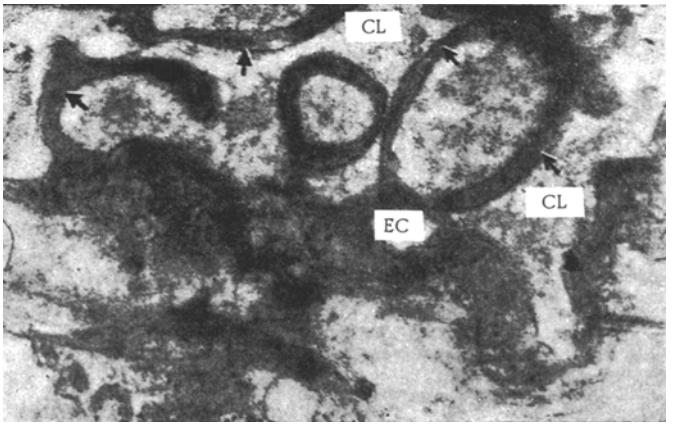

Fig. 2. Cytoplasmic projections on luminal surface of capillary endothelium in rat myocardium during fatigue after nonrepetitive physical exertion. CL) capillary lumen; EC) endothelial cell with numerous micropinocytotic vesicles. Arrows mark cytoplasmic projections, 50,000 ×.

The endothelial cells in many capillaries formed numerous projections of their cytoplasm into the lumen. In some cases the length of these projections was 3 μ. The cytoplasmic projections could have their free end in contact with the surface of the endothelium. A certain proportion of the capillaries was lined with a narrow endothelial layer with a smooth luminal surface.

Collections of polysomes arranged as rosettes and chains were found in the cytoplasm of some endothelial cells. Large collections of polysomes also were observed in the cytoplasm of the pericytes. In the subsarcolemmal zones alongside the myocardiocytes there were aggregations of small cell granules, in some cases arranged as rosettes and chains.

The organ-specific features of the myocardial capillaries under normal conditions – active micropinocytosis in the endothelium [8] and the formation of cytoplasmic endothelial projections [7] – are exhibited particularly clearly when the function of the organ is changed under certain conditions. As was shown above, micropinocytosis and the formation of cytoplasmic endothelial projections were considerably activated during physical exertion. The increased micropinocytosis was evidence of increased capillary permeability, associated with the increased quantity of metabolites required by the myocardiocytes. At the stage of fatigue this increase in permeability evidently exceeds the normal limits, as a result of which edema fluid accumulates in the pericapillary space. Electron-microscopic analysis of the ultrastructure of the capillary

wall showed increased permeability at the stage of physical work described. Besides an increase in the number of micropinocytotic vesicles, another factor contributing to the increased permeability was the appearance of numerous cytoplasmic endothelial projections of varied shape and length (Fig. 2).

The increase in the number of polysomes in the cytoplasm of the endothelium and pericytes was connected with increased protein synthesis in the capillary wall to provide for the supply of materials needed for the increased functional activity of the capillaries. Inductive effects of the myocardiocytes and, possibly, the direct passage of RNA into the capillary wall from the muscle cells, where polysomes and ribosomes were frequently seen in the subsarcolemmal zone, likewise cannot be ruled out. The appearance of many polysomes in the capillary endothelium of the hypertrophied human myocardium was described previously [1]. The harmonious response of the parenchymatous cells and capillaries and the possibility of the transfer of RNA granules from the parenchymatous cells into the endothelium have already been mentioned in the literature [8].

The structural heterogeneity of the capillaries is noteworthy. In some capillaries the endothelium was narrow, its cytoplasm contained few micropinocytotic vesicles, and the luminal surface of the endothelial cells was smooth. The ultrastructure of other capillaries (level of micropinocytosis, increase in the number of endothelial cytoplasmic projections) reflected a sharp increase in their functional activity. This heterogeneity and heterotopia of the structural features and functional activity of the capillaries is evidently linked with the focal pattern of the structure and function of the myocardium itself, to which attention has repeatedly been drawn [6, 9].

The results characterizing changes in the structure of the myocardial capillaries of rats during fatigue after physical exertion point to some possible morphological mechanisms of pathological changes in the heart.

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