ULTRASTRUCTURE OF THE HEART MUSCLE IN EXPERIMENTAL TONSILLOGENIC MYOCARDIAL DEGENERATION OF NEUROGENIC ORIGIN

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A histological and electron-microscopic study was made of the myocardium of rabbits after the induction of neurogenic myocardial degeneration by repeated injections of sterile quartz sand into the peritonsillar region. The dynamics of the morphological changes indicate the important role of circulatory disorders in the production of neurogenic myocardial degeneration. The combination of ultrastructural changes in the myocardial cells in neurogenic degeneration is indicative of anoxia. The anatomical basis of experimental tonsillogenic myocardial degeneration is a reversible focal lesion of the myocytes, usually producing contracture, superposed on circulatory disorders.

Considerable attention has been paid to the study of the pathogenesis of neurogenic disturbances of the myocardium [2]. However, their morphological basis has so far received little study.

This paper describes the results of a histological and electron-microscopic study of the myocardium of rabbits in which the receptors of the tonsils were stimulated mechanically. Such a focus of pathological impulse activity can play an important pathogenic role in the development of rheumatic carditis [11, 12].

EXPERIMENTAL METHOD

Experimental tonsillogenic myocardial degeneration was produced in 24 chinchilla rabbits weighing 2.5-3 kg by repeated injections of 20-40 mg sterile quartz sand alternately into the right and left peritonsillar regions at intervals of 4-5 days. The 16 control rabbits received injections of 0.2 ml physiological saline into the peritonsillar regions or subcutaneous injections of sterile quartz sand into the cervical region in accordance with the same timetable. The development of myocardial degeneration was monitored electro- and phonocardiographically and biochemically [1, 3, 13, 14, 19]. The animals were decapitated 20, 40 and 60 days after the beginning of the experiment. Myocardial tissue from the auricles, ventricles, and ventricular septum was fixed with formalin and embedded in paraffin wax. Sections were stained with hematoxylin-eosin, picrofuchsin, and by Selye's method [18]. Small pieces of tissue for electron microscopy were fixed, dehydrated, and embedded in Araldite. Succinate dehydrogenase activity [23] also was determined in the myocardium. Semithin sections stained with azure II-methylene blue were used to select areas with pathological changes. The ultrathin sections were stained with lead citrate and examined in the JEM-7 electron microscope.

EXPERIMENTAL RESULTS AND DISCUSSION

No changes could be detected by the light microscope in the heart tissue of the control animals. In sections stained by Selye's method single fuchsinophilic myocytes were present in nearly all the control animals.

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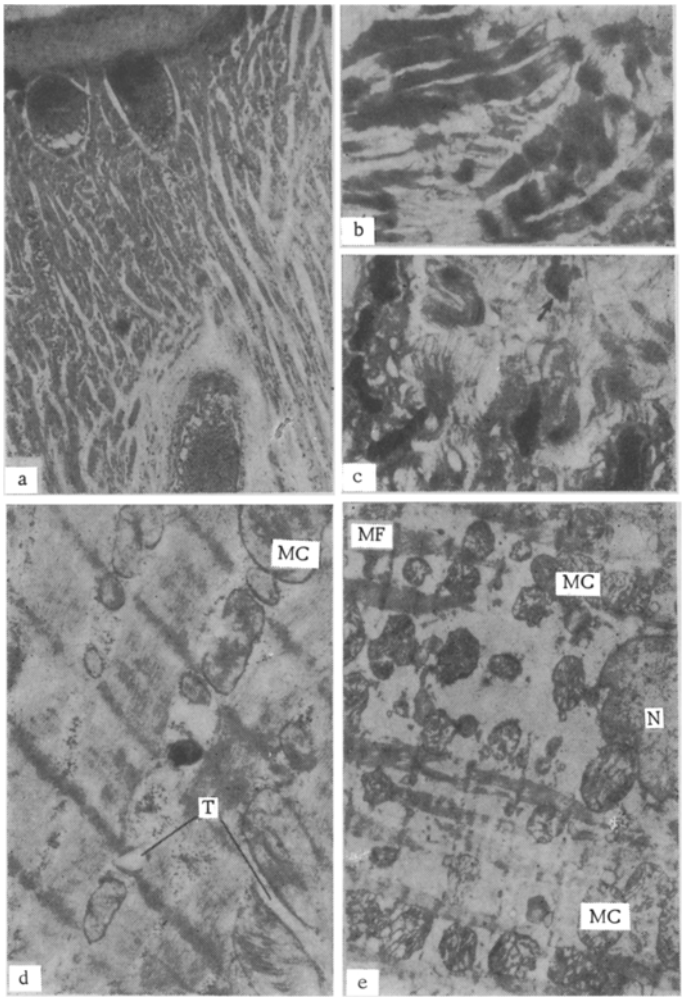

Fig. 1. Changes in myocardium during neurogenic degeneration: a) myocardium of left ventricle of rabbit on 60th day of experiment: congestion of blood vessels, perivascular and interstitial edema (hematoxylin-eosin, 56 ×); b) edematous area of myocardium of left auricle of same rabbit, contraction bands along the course of the muscle fibers (Selye's stain, 280 ×); c) fuchsinophilic myocytes (arrows) in edematous myocardium of right ventricle of rabbit on 60th day of experiment (Selye's stain, 280 ×); d) electron micrograph of part of a myocyte from right ventricle of a control rabbit: many tiny glycogen granules can be seen between the mitochondria and myofibrils (21,000 ×); e) perinuclear edema, splitting of myofibrils into bundles of protofibrils by swelling of mitochondria and absence of glycogen in myocyte from edematous zone of right ventricular myocardium on 60th day of experiment (7400 ×). MC) Mitochondrion; MF) myofibril; T) tubule of T-system; N) nucleus.

In eight experimental rabbits killed 20 days after the beginning of the experiment the myocardium was indistinguishable histologically from the myocardium of the control animals except for a slight increase in the number of fuchsinophilic myocytes.

In 7 of the 16 rabbits killed in the stage of electrocardiographic evidence of myocardial degeneration (40-60 days after the beginning of the experiments) changes whose intensity varied considerably were found in the heart. Edematous thickening of the epicardium and, to a lesser degree, of the endocardium, local separation of the epicardium from the myocardium, perivascular and interstitial edema, edematous thick-

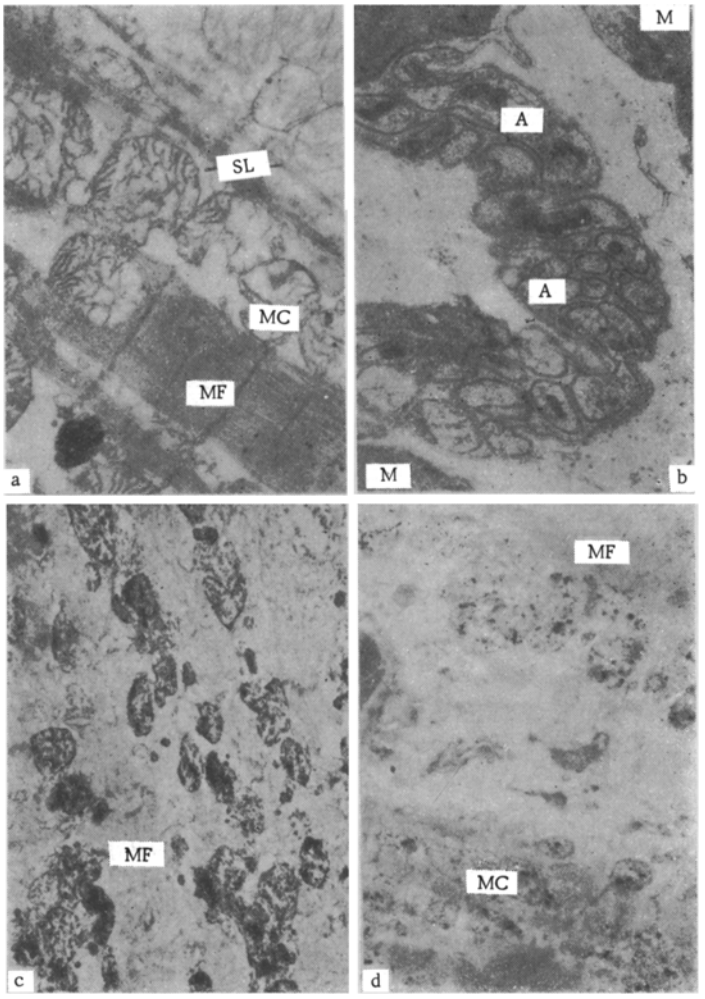

Fig. 2. Ultrastructural changes in myocardium: a) edema of sarcoplasm, disappearance of glycogen, destruction of cristae of swollen mitochondria of myocyte from edematous zone of right ventricular myocardium, 60th day of experiment (16,800 ×); b) unchanged nerve fiber in edematously widened interstitial space of right auricular myocardium, 40th day of experiment (10,250 ×); c and d) succinate dehydrogenase activity in mitochondria of right ventricular myocytes of control and experimental animals, respectively, on 60th day of experiment (c, 10,000 ×; d, 6,000 ×). SL) Sarcolemma; M) myocyte; A) axon.

ening of the vessel walls, and well-marked venous hyperemia were observed (Fig. 1a). Areas of interstitial edema were mainly connected with zones of perivascular edema. Perinuclear edema and separation of the myofibrils, together with localized contractures of the myofibrils with the formation of eosinophilic and picrinophilic "contraction bands " [15] were observed in the myocytes in the edematous zones of the myocardium (Fig. 1b). Occasionally coci of homogenization and cloudy swelling of the myocytes were found in some animals. After staining by Selye's method a clear but irregular fuchsinophilia of the sarcoplasm was found in whole groups of myocytes in the subepicardial and subendocardial zones of the myocardium and in some places in its interior. The fuchsinophilic myocytes were arranged in mosaic fashion or in bands (Fig. 1c).

The ultrastructure of the myocytes from intact areas of the myocardium was unchanged (Fig. 1d). Slight swelling of the mitochondria and dilatation of the tubules of the sarcoplasmic reticulum were observed only in individual cells.

Changes in the organelles in myocytes from areas with marked edema were considerable (Fig. 1e). Severe edema of the sarcoplasm was accompanied by a decrease in the glycogen content, separation of the myofibrils, and splitting of myofibrils into bundles of protofibrils. Translucency of the nucleoplasm was observed in the nuclei and the perinuclear space was widened locally. Many mitochondria were swollen, their matrix was translucent, and the cristae were fragmented or loosely arranged (Fig. 2a). Sometimes individual areas of the myocytes appeared vacuolated because of dilatation of the T-tubules. Contracture of several sarcomeres was combined with rupture of the protofibrils of neighboring sarcomeres and sometimes with complete disorganization of the architectonics of the myocyte. Lysosomes, auricular granules, sarcolemma, and intercalated discs were unchanged. Succinate dehydrogenase activity in the swollen mitochondria was appreciably reduced (Fig. 2c, d).

The changes in the organelles differed in degree in different myocytes and even in different parts of the same cell. The changes in the auricle and ventricle were identical in character.

The capillary endothelium usually was unchanged, but occasional endothelial cells with translucent cytoplasm and swollen mitochondria were found.

Edematous changes sometimes were observed in the cytoplasm of the Schwann cells accompanying the axons, but no visible changes were present in the axons themselves (Fig. 2b).

The morphological picture of neurogenic myocardial degeneration of different genesis is usually dominated by circulatory disturbances [2, 6, 21, 24], but degenerative and necrobiotic changes in the myocytes leading to focal necrosis and fibrosis of the myocardium also are present. In the present experiments changes in the myocytes of the "contracture degeneration" [15] or "contracture dystrophy" [5] type only rarely ended in necrosis and no cellular reaction was observed around the foci of cloudy swelling of the myocytes. Foci of necrosis with an inflammatory reaction terminating in scar formation perhaps are not characteristic of the experimental model of myocardial degeneration used or did not have time to develop.

Submicroscopic changes in the myocytes from the affected zones of the myocardium point to some degree of anoxia in them. Similar but less marked changes in the organelles of myocytes have been described in mice after intracranial injection of blood. Such lesions of the myocardium are called "ischemic cardiomyopathy of neurogenic nature" [22]. Reduced succinate dehydrogenase activity in the swollen mitochondria of the injured myocytes has also been described in myocardial degeneration of the myocardium deduced by electrical coagulation of the anterior hypothalamus [8]. Stoida [20] describes a decrease in the rate of respiration and oxidative phosphorylation in the myocardial mitochondria after division of the vagosympathetic nerve in dogs.

Myocardial degeneration can be regarded as "marked disturbances of the normal course of intracellular physiological regeneration of the ultrastructures and of the molecular processes lying on its basis" [17]. Nervous regulation of tissue nutrition ensures the "lability of the rhythm of intracellular regenerative processes" [17] – an important mechanism of tissue adaptation to changing environmental condition and a disturbance of nervous regulation consequently limits the adaptive powers of the cells and leads to their degeneration.

Diffuse-focal fuchsinophilia of the myocytes has also been described in myocardial degeneration after electrical coagulation of the anterior hypothalamus [8]. Fuchsinophilia is regarded as an initial manifestation of degeneration in the myocytes reflecting changes in their staining properties although their general morphology remains relatively intact. It is widespread in rheumatic carditis [7, 9, 16] and is connected with a disturbance of the electrolyte balance [7, 10, 18].

The dependence of the degree of fuchsinophilia on the duration of existence of the tonsillar focus generating nervous impulses is very interesting. In experimental tonsillogenic myocardial degeneration biochemical distrubances appear initially in the region of the posterior nucleus of the hypothalamus and are followed by diffuse disturbances of bioelectrical activity of various structures of the hypothalamus and hippocampus with involvement of the sympathico-adrenal system in the process [4]. This form of myocardial degeneration can thus be assumed to develop as the result of a neurodystrophic process arising under the influence of pathological impulses from the peritonsillar region and upsetting the central regulatory mechanisms.

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