Myocardial Ultrastructural Modification in Rat Heart-Lung Preparation Failed under Two Different Haemodynamic Conditions

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Received September 15, 1969

Ultrastrukturveränderungen des Herzens in Herz-Lungen-Präparaten bei zwei verschiedenen hämodynamischen Bedingungen

Zusammenfassung. Es werden die von zweierlei Herzdekompensationen am Herz-Lungen-Präparat bewirkten ultrastrukturellen Veränderungen des Rattenmyokards untersucht.

Die Herzdekompensation wurde unter den folgenden verschiedenartigen hämodynamischen Arbeitsbedingungen hervorgerufen: 1. beim arteriellen Hochdruck und hohen Herzmittenvolumen („belastungsbedingtes Herzversagen“) oder 2. beim mäßigen arteriellen Blutdruck und mäßigen Herzmittenvolumen („spontanes Herzversagen“).

Im Zusammenhang mit den verschiedenen Arten von Herzdekompensation sind verschiedenartige ultrastrukturelle Veränderungen am Herzmuskel zu beobachten, und zwar: beim „belastungsbedingten Herzversagen“ treten stellenweise Veränderungen an den Mitochondrien hervor, die verschwollen, mit fragmentierten Cristae und heller Matrix erscheinen; beim „spontanen Herzversagen“ sind zahlreiche den Mitochondrien nahe zerstreute Fetttröpfchen vorhanden.

Die Herzdekompensation scheint dem Muskelfibrillenapparat nicht zu schaden.

Die möglichen Zusammenhänge zwischen den obengenannten ultrastrukturellen Veränderungen und den in früheren eigenen Arbeiten beschriebenen Stoffwechseländerungen werden besprochen.

Summary. The ultrastructural alterations of heart muscle cells, induced by two types of cardiac failure in rat heart-lung preparation, have been investigated.

Heart failure was obtained by imposing on the heart two different haemodynamic load conditions: 1) high mean arterial blood pressure and high cardiac output (load failure) or 2) moderate mean arterial blood pressure and moderate cardiac output (spontaneous failure).

Different ultrastructural alterations were observed in the hearts in relation to these different types of heart failure: "load failure" caused patchy alteration of mitochondria that appeared swollen, with broken cristae and pale matrix; "spontaneous failure", on the other hand, resulted in the appearance of many scattered lipid droplets close to the mitochondria.

Cardiac failure did not appear to affect the myofibrillar apparatus.

The possible relationship between the above ultrastructural alterations and the metabolic changes reported in previous papers are discussed.

Introduction

The effects of heart failure on morphological appearance of myocardial tissue have been investigated by many Authors.

Several electron microscopic studies have pointed out myocardial ultrastructural changes in man and in animals under a number of experimental conditions.
Cardiac failure produced by chronic aortic stenosis in dogs, caused evident alterations of the mitochondria (Wollenberger, 1961); they appeared elongated with cristae more or less disorderly arranged. No alteration was evident in the myofibrillar apparatus.

In the first stage after operative narrowing of the aorta (dog and rabbit), Parin and Meerson (1959) showed myocardial deposition of neutral fat droplets as consequence of a diminished fatty acid oxidation. Ferrans et al. (1965) found, in human alcoholic cardiomyopathy, degenerative myofibrillar alterations, lipid droplets deposition and swollen mitochondria with disarrangement of the cristae together with swollen endoplasmic reticulum.

From the mentioned literature it is well established that the myocardial morphological alterations in failing heart are very dissimilar to each other and sometimes of conflicting appearance.

The aim of this study is to find out if these different kinds of morphological changes are somehow connected with different types of cardiac failure.

In order to verify this hypothesis we carried out two types of heart failure by imposing rat hearts under distinct haemodynamic work conditions, checking if the morphological aspect of myocardial damage was dissimilar in the two types of failure.

We utilized the rat heart-lung preparation (HLP) because with this experimental procedure, heart failure can be obtained under haemodynamic conditions strictly controlled and reproducible, in animals of the same stock, body and dietary conditions.

The myocardial samples from our experiments have been observed under light and electron microscope.

Material and Methods

Fifteen HLPs were obtained from male albino rats (230 g body weight) under light ether anesthesia. The experimental procedure can be summarized as follows.

After the establishment of positive pressure ventilation with a small Starling pump, a midline incision was made in the abdomen and chest and two cannulae were inserted; the first into the inferior vena cava below the diaphragm and the second one into the ascending aorta above the origin of the innominate artery. The whole procedure takes 5–6 min (Minelli, 1961). The extracorporeal circuit was the same as that used by Starling in the dog, adapted for the small size of the rat.

The recirculating fluid (80 ml in total) was constituted by blood obtained from donor rats diluted 1:4 with Ringer-Lock’s solution containing 3.5% polyvinylpyrrolidone.

Cardiac output was measured with a modified Pitot flowmeter.

Arterial blood pressure and heart rate were monitored with a Statham pressure transducer and graphically displayed on a Samborn recorder.

Heart failure was experimentally produced using two different and strictly controlled haemodynamic conditions:

1) or by working the heart briefly (13 ± 2 min) under elevated haemodynamic load (“Load heart failure”),

2) or by working the heart for a longer period of time (135 ± 5 min) under moderate haemodynamic load (“Spontaneous heart failure”).

In order to obtain the “load heart failure”, high mean arterial blood pressure (BP = 108 mm Hg) and high cardiac output (CO = 46 ml/min) were imposed on the heart at the beginning of the extracorporeal circulation (4 HLPs); the survival time of these preparations with no evident signs of cardiac failure did not exceed 13 ± 2 min.