BIOMECHANICS

CHANGES IN THE MECHANICAL PROPERTIES OF HUMAN CORONARY ARTERIES WITH AGE*

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The problem of the study of the mechanical properties of human coronary arteries is becoming increasingly important because of the prophylaxis and treatment of cardiovascular diseases. The development of operative treatment of these diseases required more accurate experimental data on the mechanical properties of the walls of the coronary vessels and their changes with age, on the deformative properties of the cardial arteries themselves, and of those of the substitutes used for an affected segment.

However, until now studies of the mechanical properties of coronary arteries have been carried out on dogs only [1-5]. There are no such data in the literature for man. In [1-5] only the superior (proximal) segment of the left coronary artery of practically healthy dogs was used, and no attention was paid to the changes in the vessels with age. In [1, 3, 4] it was noted that with increase in the intravascular pressure from 70 to 120 mm Hg, the vessel segment increases in volume by 22 to 43%. If the upper boundary of the physiological norm is exceeded, the vessel becomes less elastic [2]. It was shown [4] that if the experiment is performed a few hours after the death of an animal, there are no changes in the mechanical properties of the coronary vessels. The mean tangential elastic modulus, determined in [5] at a pressure of 140 mm Hg, was equal to 0.034 kgf/mm², which practically corresponds to the elastic modulus of the arterial vessels of a muscular type of a dog.

The parameters found for the mechanical properties of the coronary arteries of a dog can be used only for an approximate evaluation of the corresponding parameters in man. They are practically useless for solving the problem of reconstructing these arteries in a sick person or when producing various substitutes of cardial vessels.

The clinical data on vascular surgery show that in 12% of cases, the atherosclerotic obstructions of central vessels in man are local in character, and this affection is usually observed in the superior (proximal) parts of coronary arteries. The aim of the present work was to study the mechanical properties of separate parts of the two main central vessels of the human heart, which ensure the supply of a large part of the cardial muscle (Fig. 1), and to find changes in these properties with age. According to [6], the minimum diameter of the right coronary artery is 1.59 mm, and the maximum diameter is 4.15 mm (2.71 mm on average). The left coronary artery, with a short basilar trunk, is divided into two large branches: the anterior descending branch and the circumflex branch. The minimum diameter of the descending branch of the left coronary artery, which is a continuation of the basilar trunk, is 1.91 mm, and the maximum diameter is 3.80 mm (2.68 mm on average). The circumflex branch of the left coronary artery has the largest mean diameter — 2.90 mm (minimum diameter, 1.59 mm; maximum, 4.15). The left and right coronary arteries are situated in grooves above the cardial muscles under the epicardium and branch on its surface. The thin arteries, which emerge from the two main arteries, penetrate the mass of the muscles at a right angle and tightly press the posterior wall of the main artery to the myocardium. Therefore, the basilar trunks of the coronary arteries continuously relax and contract into diastolic and systolic flow. In general, the mechanical contractions of the myocardium influence the branched network of the thin vessels.

As the experimental material we used cylindrical segments of the superior (proximal) and inferior (distal) parts of right coronary artery and the anterior descending branch of the left coronary artery. The vessels were removed during an autopsy of 40 male human beings (19 to 76 years old, who had died of injuries or as

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the result of diseases not related to direct complications of atherosclerosis of the coronary arteries. The material was divided into three age groups: 1) coronary arteries taken from 15 young people (from 19 to 29 years old) with no symptoms of atherosclerosis; 2) vessels from 15 middle-aged people (from 30 to 49 years old) with first or second stages of atherosclerosis according to the World Health Organization (WHO) scale; 3) vessels from 10 old people (50 to 76 years old), in which the arteries showed visible symptoms of atherosclerosis, but without sedimentation of calcium salts. After they had been removed from the vascular bed under the epicardium, the two coronary arteries were thoroughly purified from the surrounding tissues. From their proximal and distal parts (see Fig. 1), we cut branchless segments of vessels 15-20 mm long. The ends of each vascular segment were immobilized on metallic fixing cannulae of a corresponding diameter (from 0.6 to 2.5 mm). The vessel segments were stored together with the cannulae in a physiological solution at a temperature of 21 ±1°C. The vessels were studied not more than 15 h after the death of the individual.

The initial wall thickness of the superior and inferior parts of the two coronary arteries not subjected to a load was measured from the lateral microscopic section under an MPSU-1 microscope (accurate to within ±0.01 mm).

The mechanical properties of the walls of the coronary arteries were studied in a special chamber (Fig. 2) with optically transparent walls, so that it was possible to see and photograph the deformation of the vessel segment in transient light through a microscope. The sample of the vessel was placed in a chamber with a liquid at a constant temperature of 37.5 ±1°C (regulated by a thermostat), flowing continuously. The intravascular pressure in the vessel segment and in the experimental apparatus system, which has been described in detail in [7], was produced by forcing the physiological solution through a Bobrov apparatus. The pressure was measured by a mercury manometer (with a scale division of 0.2 mm Hg). The test was carried out on a vessel held preliminarily under tension by an axial force P of 2.0 ±0.2 gf, maintained constant during the experiment. The longitudinal stretching force of the segment was measured by a tensiometric ISD-3 dynamometer (accurate to within ±0.2 gf). The intravascular pressure in the vessel was gradually increased from 0 to 240 mm Hg in steps of 20 mm Hg. Each pressure stage was maintained for 30 sec, and the segment was...