FORCE AND VELOCITY OF CONTRACTION OF THE VENTRICULAR MYOCARDIUM

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The force and velocity of myocardial contraction of the left ventricle is higher than that of the right, both at relative physiological rest and when the ventricles are working under isometric conditions (compression of the aorta or pulmonary artery, respectively).

There is considerable evidence in the literature to show that the intraventricular pressure and work of the left ventricle are from 4 to 5 times greater than those of the right, but it characterizes only ventricular function as a whole without indicating what differences exist in the functional characteristics of the myocardial tissue of the left and right ventricles.

The object of this investigation was to compare the force and velocity of contraction of the left and right ventricles as a whole, and also of the myocardial tissue composing them.

EXPERIMENTAL METHOD

Acute experiments were carried out on 10 male rats weighing 180-200 g anesthetized with urethane (160 mg/100 g body weight) and artificially ventilated with air. After thoracotomy, cannulas connected to a "Barovar" electromanometer were introduced into the ventricles. The intraventricular pressure was recorded on a type 6NEK=1F_2 electrocardiograph.

The rate of change of pressure in the ventricles was recorded by means of a differential system. Parameters of the force and velocity of contraction were determined for each ventricle both at relative physiological rest and during maximal loading caused by complete occlusion of the aorta or pulmonary artery, respectively, after occlusion for 5 sec.

The index known as the intensity of functioning of structures, given by the quotient of the intraventricular systolic pressure divided by the weight of the ventricles, was used as the parameter characterizing the force of contraction of the muscle tissue. The weight of each ventricle was obtained by weighing the free part of the left and right ventricles (the "sails" of the ventricles) separately, after which the intaventricular septum was weighed and its weight divided between the ventricles in the same proportion as the ratio between the weights of the "sails" of the right and left ventricles.

As an index of the velocity of contraction, the contractility index [11] was used. This is obtained by dividing the maximal velocity of increase in pressure in the isometric phase of contraction of the ventricle by the intraventricular pressure at the velocity maximum.

EXPERIMENTAL RESULTS AND DISCUSSION

At relative physiological rest, the systolic pressure in the left ventricle was 3.4 times higher than in the right, and the intensity of functioning of structures (IFS), reflecting the force of myocardial contraction, was 1.4 times greater than in the right (Table 1). It should be remembered, however, that the difference in force of myocardial contraction of the ventricles could be due to differences in the degree of stretching of the fibers resulting from differences in factors controlling the inflow of blood into the two ventricles. In accordance with Hill's theory, the velocity of contraction is inversely proportional to its force, so that it might be expected that the velocity of myocardial contraction of the left ventricle would be lower than that of the right. However, as Table 1 shows, the contractility index of the myocardium of the left ventricle was certainly higher than in the right ventricle.

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TABLE 1. Indices of Contractile Function of the Left and Right Ventricles at Relative Physiological Rest

Index	Left ventricle (l.v.)	Right ventricle (r.v.)	Ratio between indices l.v./r.v.	P
Weight of ventricle (in mg)	398 ± 25.2	159 ± 5.9	2.5	< 0.001
Final diastolic pressure (in mm Hg)	2.75 ± 0.5	0.78 ± 0.22	3.5	< 0.001
Systolic pressure (in mm Hg)	79 ± 7.95	23.2 ± 1.57	3.4	< 0.001
Index of intensity of functioning of structures (in mm Hg/100 mg)	19.8 ± 1.86	14.3 ± 0.9	1.4	< 0.02
Maximal velocity of increase in pressure (in mm Hg/sec)	2250 ± 194	462 ± 33	4.9	< 0.001
Contractility index	94.0 ± 6.1	56.5 ± 5.95	1.66	< 0.01

TABLE 2. Indices of Contractile Function of the Left and Right Ventricles During Work Under Isometric Conditions

Index	Left ventricle (l.v.)	Right ventricle (r.v.)	Ratio between indices l.v./r.v.	P
Weight of ventricle (in mg)	384 ± 14.5	163 ± 4.6	2.36	< 0.001
Frequency of contractions	175 ± 8.2	178 ± 10.8	0.98	> 0.1
Final diastolic pressure (in mm Hg)	15.2 ± 1.72	3.6 ± 1.34	4.22	< 0.001
Systolic pressure (in mm Hg)	210 ± 13.2	49.6 ± 6.1	4.25	< 0.001
Maximal intensity of functioning of structures (in mm Hg/100 mg)	58.0 ± 4.8	30 ± 2.1	1.93	< 0.01
Maximal velocity of increase in pressure (in mm Hg/sec)	4910 ± 695	1040 ± 147	4.71	< 0.001
Contractility index	51.0 ± 3.85	43.6 ± 12.8	1.17	> 0.1

In the second part of the investigation, the maximal force of myocardial contraction of the ventricles was determined during work under isometric conditions. The IFS index, reflecting the force of myocardial contraction of the ventricle, in accordance with the Frank–Starling law, is dependent on the initial length of the muscle fibers. Preliminary experiments showed that the systolic pressure in the left ventricle reaches a maximum when the final diastolic pressure is 10-15 mm Hg, and remains unchanged with a further increase in the final diastolic pressure. The systolic pressure in the right ventricle reached a maximum at values of the final diastolic pressure of between 1 and 3 mm Hg. The contractile function of the myocardium of the ventricles was therefore compared under conditions of maximal mobilization of the Frank–Starling mechanism.

The results of these experiments are given in Table 2, which shows that the systolic pressure in the left ventricle was 4.25 times higher than in the right, and the IFS index was 1.93 times higher. This means that under isometric conditions the maximal force of myocardial contraction of the left ventricle is higher than that of the right.

The most important fact discovered by this investigation is that the force and velocity of myocardial contraction of the left ventricle are higher than those of the right.

These results show good agreement with data indicating a higher concentration of myofibrillary proteins in the myocardium of the left ventricle [1,3,8], with data indicating that the intensity of the fundamental processes of energy transformation in the myocardium of the left ventricle is higher than in the right [3-7,9,10], and also with data indicating that the intensity of renewal of the cation reserve is higher in the myocardium of the left ventricle [2].

LITERATURE CITED

1. N. V. Karsanov, in: Heart Failure and Arrhythmias [in Russian], Leningrad (1966), p. 28.
2. V. I. Mil'ko and B. M. Shchepotin, in: Current Problems in Cardiology [in Russian], Kiev (1965), p. 189.
3. G. V. Chernysheva, Abstracts of Proceedings of an All-Union Conference on Muscle Biochemistry [in Russian], Moscow-Leningrad (1966), p. 143.

4. G. Biörck, Acta Med. Scand., 154, 305 (1956).
5. G. C. Dalli and P. Chiaverini, Minerva Cardiol., 7, 578 (1959).
6. A. Greco, M. Magaro, S. Sensi, et al., Boll. Soc. Ital. Biol. Sper., 36, 883 (1960).
7. Kong-oo Goh and R. D. Dallam, Am. J. Physiol., 188, 514 (1957).
8. J. Kovats, Nature, 163, 606 (1949).
9. J. L. Poland and D. H. Blount, Proc. Soc. Exp. Biol. (N.Y.), 121, 560 (1966).
10. L. Szekeres and G. Lichner, Acta Physiol. Acad. Sci. Hung., 21, 243 (1962).
11. U. P. Veragut and H. P. Krayenbühl, Cardiologiya (Basel), 47, 96 (1965).