STUDY OF THE PHASE STRUCTURE OF CARDIAC CONTRACTION AND SOME LEFT-VENTRICULAR HEMODYNAMIC INDICES OF SMALL LABORATORY ANIMALS

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The phase structure of the cardiac contraction was determined from the curves of pressure in the left ventricle and in the carotid artery, recorded synchronously with the ECG in rabbits and rats during surgical pneumothorax and artificial respiration. A significant direct correlation was found between the duration of the cardiac cycle and the duration of the individual phases of systole and diastole.

The phase structure of the cardiac cycle in small laboratory animals (rats and rabbits), by contrast with larger animals (cats and dogs), has been inadequately studied. Considerable interest in this subject has been aroused by investigations of the phase structure of the cardiac cycle in rabbits and rats by the method of polycardiography [4, 6, 7]. However, the most precise method is that of determining the phase structure from the curves of pressure within the chambers of the heart and in the great vessels.

This paper describes the results of an investigation of the phase structure of contraction of the left ventricle in normal rabbits and rats from the curves of pressure in the left ventricle and in the carotid artery.

The intracardiac hemodynamics and phase structure of cardiac contraction were investigated in acute experiments on 20 healthy rabbits and 20 rats anesthetized with chloralose and urethane (50 mg/kg and 1 g/kg respectively) during open pneumothorax and artificial respiration. The curves of pressure in the left ventricle and in the carotid artery were recorded in each animal consecutively and synchronously with the recording of the ECG in leads I and II with a tape winding speed of 50-100 mm/sec. The curves were recorded on a type ÉKG 5-01 Hungarian five-channel electrocardiograph. The pressure was measured by means of special polyethylene catheters. The end of one of them, drawn out into a point like a needle, was introduced into the carotid artery, while the other, connected to a needle, was inserted into the left ventricle. Essential conditions for the work were stability of the zero marker and equal amplification during recording of the pressure curves in the left ventricle and carotid artery. From the curves thus obtained, the pressures in the various periods of the cardiac cycle were determined in wave complexes of equal duration, and the phase structure of cardiac contraction was studied.

The phase of asynchronous contraction was determined from the curve of intraventricular pressure in the S–r interval. The point S coincided in time with the beginning of the Q wave of the ECG while the point r coincided with the apex of the R wave [1]. The point r also served as the origin of the phase of isometric contraction (r–K). Its end determined the point K which lay on the curve of intraventricular pressure and its distance from the zero line gave the diastolic pressure in the carotid artery. The point K also served as the origin of the phase of expulsion (K–h). Its end on the curve of intraventricular pressure was determined by the point m, corresponding in time to the end of the T wave of the ECG [1]. This point was chosen because of the lack of clarity and sometimes the absence of the incisura on the descending

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TABLE 1. Phase Structure of Left-Ventricular Systole in Healthy Rabbits and Rats (in sec; M ± m)

	R–R (msec)	Rhythm (in beats per minute)	Duration of periods of ventricular systole		
			EMS	diastole	asynchronous contraction
Rabbits	0,20±0,002	300,0	0,122±0,001	0,077±0,002	0,01±0,0001
Rats	0,15±0,005	400,0	0,084±0,004	0,065±0,002	0,01±0,0001
P	<0,001		<0,001	<0,001	

	Duration of periods of ventricular systole				
	isometric contractions	period of contraction	expulsion	ventricular diastole	atrial systole
Rabbits	0,049±0,001	0,059±0,001	0,063±0,001	0,036±0,001	0,041±0,001
Rats	0,031±0,001	0,041±0,0001	0,043±0,001	0,031±0,001	0,034±0,001
P	<0,001	<0,001	<0,001	<0,01	<0,001

TABLE 2. Relationship between Duration of Cardiac Contraction and Corresponding Phases in Rabbits and Rats

	Phase of cardiac contraction	r	R^1	y=ax+b
Rabbits	Expulsion (E)	0,618	0,338	E=0,333·RR—0,003
	Diastole (D)	0,729	0,500	Д=0,500·RR—0,022
Rats	Isometric contraction (I)	0,734	0,246	И=0,246·RR—0,004
	Expulsion (E)	0,313	0,302	E=0,302·RR—0,001
	Diastole (D)	0,911	0,475	Д=0,475·RR—0,007

*Coefficient of regression.

part of the curve of pressure in the carotid artery used to determine the end of the expulsion phase and the duration of proto-diastole [8]. The interval S–n corresponded to the duration of electromechanical systole (EMS), i.e., the time during which contraction and expulsion take place.

Diastole of the ventricle corresponded to the interval n–h. The point h was found by dropping a perpendicular to the curve of intraventricular pressure from the middle of the P wave of the ECG. Atrial systole was determined by the interval h–S.

Unlike other methods [4, 6, 7], this method thus predetermines the shorter duration of the phase of asynchronous contraction and the longer duration of the phase of isometric contraction.

The systolic pressure in the left ventricle of rabbits was 102 ± 3.0, and in rats 101 ± 5.0 mm Hg. The final diastolic pressure in the left ventricle was 2.0 ± 0.2 and 1.3 ± 0.4 mm Hg, respectively. The systolic pressure in the carotid artery was virtually indistinguishable from the pressure in the left ventricle, while the diastolic pressure was 70.0 ± 0.3 mm Hg in rabbits and 61.3 ± 8.0 mm Hg in rats.

Comparison of these results (Table 1) with those in the literature [4, 6, 7] obtained by the method of polycardiography with a closed thorax showed that in both rabbits and rats the phase of asynchronous contraction was much shorter while the phase of isometric concentration was much longer.

In the present experiments the open pneumothorax could have had a definite effect on the duration of the phases of systole and diastole, for with the faster rhythm there was a relative increase in the duration of the contraction period and shortening of the expulsion period [3, 8].

Despite the marked difference in the duration of the periods of contraction and expulsion, the duration of the EMS according to these observations was closely similar to that found by other workers [4, 7].

To investigate the presence and character of correlation between the duration of the individual phases of the cardiac cycle and the heart rate in rabbits and rats, the appropriate coefficients of correlation (r) were calculated (Table 2). As Table 2 shows, in rabbits the duration of the phases of expulsion and diastole was closely correlated with the duration of the cardiac cycle. In rats this correlation was observed for the phases of isometric contraction, expulsion, and diastole.

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