Synchronization and Desynchronization of the "Hypertensive" Heart

V. A. Frolov, G. A. Drozdova, T. A. Kazanskaya, and P. Ramdavon

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As we have previously shown [3,4], there is a reliable strong positive correlation between the parameters characterizing the real and potentially attainable contractility of the ventricles in the intact heart, whereas under conditions of the development of a pathological process these relationships weaken, this being indicative of a disturbed activity of the heart as a dynamically synchronized system. The disturbed synchronicity of the activity of different portions or even regions of the heart has been noted in a number of pathological states [1,5,7], this desynchronization probably leading to disturbances of the heart rhythm as well as to a reduction of the reserve of myocardial contractility. Since this problem has received practically no attention in the current literature on the pathogenesis of arterial hypertension and its treatment [6,8,9], in the present study we analyzed the level of heart synchronicity at different stages of development of hypertension.

MATERIALS AND METHODS

Experiments were carried out on 549 male Chinchilla rabbits weighing 2.5-3.5 kg. Renoprival arterial hypertension, caused by surgical occlusion of the abdominal aorta by one-third of its initial diameter above the site of origin of the right renal artery, served as a model. As the result of this operation, a pronounced arterial hypertension developed in the animals, three distinct pathogenetic stages having been previously distinguished by us in its dynamics [2]: onset of compensation (1 to 4 weeks); compensation (6 to 10 weeks); and decompensation (22 to 52 weeks). On weeks 1, 2, 4, 6, 8, 10, 22, 26, and 52 after the operation un-

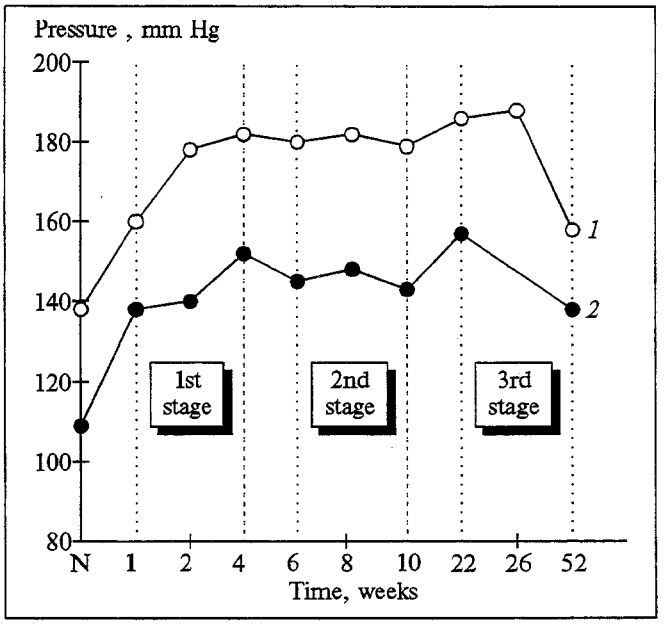

Fig. 1. Dynamics of systolic (*1*) and diastolic (*2*) arterial pressure in experimental animals over 52 weeks after occlusion of abdominal aorta.

Department of Pathological Physiology, Russian Peoples' Friendship University, Moscow. (Presented by N. A. Agadzhanyan, Member of the Russian Academy of Medical Sciences)

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der conditions of acute experiment, the systolic and diastolic arterial pressure (for monitoring the development of arterial hypertension), as well as the intraventricular peak (real) systolic pressure in the cavities of the left ventricle (LV) and right ventricle (RV) (RAP_{lv} and RAP_{rv}, respectively) were electromanometrically registered in both the control animals and the hypertensive rabbits with the aid of a Mingograf-81 electrocardiograph by cannulating the corresponding cardiac cavity; the ascending aorta (for LV) and pulmonary artery (for RV) were then subjected to a 5-sec occlusion, and the maximal developed pressure (MDP_{lv} and MDP_{rv}) was recorded in these portions of the heart. The data obtained were statistically processed after Student and subjected to correlation analysis on an IBM PC/AT with the aid of software developed by us. During such processing, the relationships between RAP_{lv}, RAP_{rv}, MDP_{lv}, and MDP_{rv} in all possible combinations were analyzed. The presence of a strong positive correlation between these parameters was considered to be indicative of synchronicity of the contractility of the LV and RV, and a decrease of this correlation was regarded as an indicator of ventricle desynchronization. During correlation analysis the relationship between the parameters was considered to be strong, intermediate, and weak when the absolute values of p were $p \geqslant 0.7$, $p=0.69$-0.3, and $p \leqslant 0.29$, respectively.

RESULTS

As is seen from Fig. 1, in the model used by us a pronounced arterial hypertension developed in the experimental animals.

The results of assessing heart contractility are shown in Table 1.

As follows from the data in the table, certain dynamics of the parameters of the real and maximally developed contractility of both ventricles is observed during the course of hypertension. However, in the present work we studied not this dynamics but, first of all, the correlations between the parameters shown in Table 2.

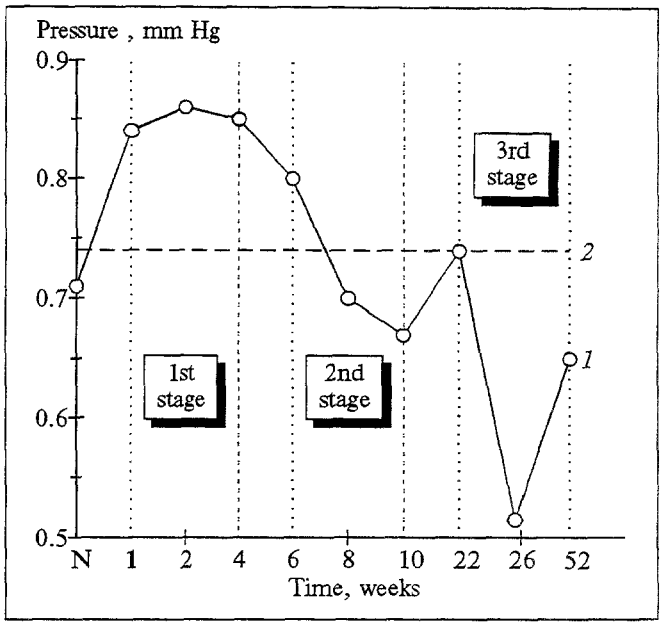

Fig. 2. Dynamics of mean absolute values of coefficients of correlation between parameters of contractility of heart ventricles in the course of renoprival arterial hypertension. *1*) mean absolute values of correlation coefficients for each time point of process; *2*) mean absolute value of correlation coefficient during the whole process.

As seen from the results presented in the table, during the course of hypertension, marked changes of the strength of the correlation between the parameters of cardiac contractility occur, being different at different stages of arterial hypertension. The general character of these changes is illustrated by Fig. 2, where the dynamics of the mean absolute value of the correlation coefficient is presented for each time point of the investigation with respect to the average level of this coefficient during the whole process.

The figure shows that the strength of the relationship between the parameters of heart ventricle contractility markedly increases in the 1st stage of the process; in the 2nd stage it reverts to a level close to the normal one, and in the 3rd stage it drops sharply.

Thus, during the stage of compensation, the heart is functioning as a more rigid system than

TABLE 1. Dynamics of Some Parameters of Contractility of Heart LV and RV in the Course of Experimental Renoprival Hypertension

Parameters, mm Hg	Control	Time after occlusion of abdominal aorta, weeks								
		1st stage			2nd stage			3rd stage		
		1	2	4	6	8	10	22	26	52
RAP_{lv}	109±4	106±5	139±12	137±10	135±9	169±14	133±6	116±5	133±10	128±7
RAP_{rv}	24±1	24±2	23±3	26±2	38±3	27±3	25±2	25±4	28±4	22±3
MDP_{lv}	196±4	214±10	232±9	233±8	237±6	264±7	235±9	224±6	220±4	228±6
MDP_{rv}	43±2	43±3	47±5	45±2	62±3	54±5	51±3	40±6	44±6	41±2

TABLE 2. Correlation between Parameters of Heart Ventricle Contractility in Experimental Renoprival Hypertension

Parts of parameters	Animal groups									
	Control	Time after occlusion of abdominal aorta, weeks								
		1st stage			2nd stage			3rd stage		
		1	2	4	6	8	10	22	26	52
$RAP_{lv} - MDP_{lv}$	+0.78*	+0.81*	+0.93*	+0.91*	+0.86*	+0.89*	+0.97*	+0.72	−0.64	+0.70*
$RAP_{rv} - MDP_{rv}$	+0.69*	+0.90*	+0.93*	+0.85*	+0.87*	+0.67	+0.06	+0.96*	−0.43	+0.47*
$RAP_{lv} - RAP_{rv}$	+0.73*	+0.81*	+0.85*	+0.91*	+0.81*	−0.63	+0.94*	+0.71	−0.29	+0.73*
$RAP_{lv} - MDP_{rv}$	+0.76*	+0.92*	+0.84*	+0.86*	+0.82*	+0.64	+0.93*	+0.66	+1.00*	+0.78*
$RAP_{lv} - MDP_{rv}$	+0.81*	+0.78*	+0.84*	+0.91*	+0.78*	−0.68*	+0.96*	+0.70	−0.46	+0.69*
$RAP_{rv} - MDP_{lv}$	+0.60*	+0.85*	+0.86*	+0.78*	+0.71*	+0.69	−0.18	+0.76	−0.21	+0.53

Note. Asterisk indicates reliable coefficients.

in the norm. Obviously, the strengthened synchronicity of the activity of the ventricles enables the heart to overcome an increased load, due to which the process shifts to the 2nd stage of compensation characterized by a new, higher level (compared to the norm) of heart activity and its regulation, as we have previously shown [2]: myocardial hypertrophy is observed, ultrastructural changes occur in it, and the parameters of cardiac contractility are altered, but on the whole the heart provides for the optimal hemodynamics during this period. At this stage the degree of synchronicity of the parameters of cardiac contractility also reverts to the initial level. During the stage of decompensation, when the heart is unable to provide the normal level of hemodynamics, and when the so-called "wear and tear of the hypertrophied myocardium" starts developing, desynchronization of the parameters of heart contractility occurs, which may underlie the development of the heart rhythm disturbances and heart failure as well. Probably, the inadequate responses of the myocardium to pharmacological factors during this period [2] may be attributed to disturbances of the activity of the heart as a system.

The data presented provide evidence that from the very beginning of the formation of the "hypertensive heart", profound disturbances occur in the relationships between the contractility of the ventricles, this being the earliest functional basis for the subsequently developing "wear and tear."

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