Parameters of Microcirculation in Hamster Buccal Pouches under Conditions of Reduced Systemic Blood Pressure

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 145, No. 1, pp. 29-34, January, 2008
Original article submitted October 2, 2006.

Laser Doppler flowmetry studies showed that blood flow in the microcirculation bed of paired buccal pouches in hamsters decreased under conditions of reduced systemic blood pressure and this decrease is more pronounced in the left pouch. The transition of the circulatory bed to the new state is step-wise in the left pouch and continuous in the right one.

Key Words: *blood flow; hamster buccal pouch; twoness; laser Doppler flowmetry*

Hypoxia irrespective of its etiology leads to functional and structural disturbances in organs and tissues. Introduction of the noninvasive method of laser Doppler flowmetry into medical practice provides new possibilities for the search of informative zones for the study of blood flow disturbances in organs and tissues and their correction [7,13] and for determining the selection criteria for the study object corresponding to its morphofunctional organization and study objectives [8]. The major trend in the studies of blood flow disturbances by the method of laser Doppler flowmetry [4] is evaluation of regulatory mechanisms [6] on the basis the analysis of blood flow fluctuations. For instance, in patients with essential hypertension (*i.e.* under conditions of chronically increased blood pressure) microcirculation parameters (MP) increased against the background of reduced blood flow variability associated with increased amplitude of high-frequency harmonic in the spectrum, which can be considered as compensatory activation of parasympathetic influences in blood flow regulation [4,5]. Under conditions of reduced blood pressure (hypotension), the myogenic and neurogenic tone of arterioles and the contribution of active mechanism of blood flow modulation decreased, but MP remained within the normal range [9]. Accumulated data on the use of flowmetry for evaluation of microcirculation of paired fragments of the skin under conditions of thermal and radiation injury [11] and in other cases (occlusion of renal vessels, during ontogeny in rat pups) showed specificity of MP in symmetrical organs and tissues.

Here we studied the dynamics of blood flow and mechanisms of its regulation in paired buccal pouches (HBP) of hamsters under conditions of reduced systemic blood pressure by the method of laser Doppler flowmetry.

MATERIALS AND METHODS

Experiments were carried out on nembutal-narcotized hamsters. Systemic blood pressure was reduced by successive injection of vasodilators (2% papaverine, intramuscularly, 20% caffeine, intraperitoneally, 0.3 ml per 100 g body weight) [12]. Blood pressure was recorded in the carotid artery on the contralateral side [12]. Blood flow in HBP was recorded for 30-35 min after injection of each drug using a LAKK-01 flowmeter (LAZMA). When blood pressure was not measured, MP of symmetrical HBP were recorded on the same animal. Blood flow parameters were analyzed using spectral analysis. Har-

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monic frequency ranges for laboratory animals were the follows: 0.02-0.20 Hz, low frequency range, where 0.02-0.06-Hz and 0.06-0.20-Hz harmonics reflect oscillations of neurogenic and myogenic nature, respectively; 0.2-0.4 Hz, high-frequency range; 0.8-1.5 Hz, respiratory rhythm; 2-5 Hz, pulse oscillations, heat rhythm [6,8]. For visual presentation of the blood flow transition to a new state, the evolution of MP was presented on a phase plane, which is determined by a set of point, where one coordinate is the variable and the second coordinate is the rate of its change with time [1,14].

RESULTS

Blood pressure in the common carotid artery after injection of papaverine and caffeine decreased by <24% and by 54.0-55.5%, respectively, from the initial level (irrespective on the side of measurement). The range of blood pressure in the left and right carotid arteries was 0.333-0.592 and 0.303-0.610, respectively, from the initial level, which prompted us to compare the characteristics of both vessels [12] and blood flow parameters in symmetrical microcirculatory beds (MCB).

After injection of papaverine, MP of the left HBP decreased (Table 1) and further decrease in systemic blood pressure little affected this parameter. On the right side, MP decreased in parallel with blood pressure decrease. The decrease in MP from the baseline was more pronounced on the left side. The sharp decrease in blood flow in MCB on the left side can be explained by a decrease in the number of functioning capillaries sensitive to blood flow changes and deceleration of blood flow in venules (according to biomicroscopy data, dilatory reactions of MCB under conditions of reduced systemic blood pressure are more pronounced on the left side [12]). MP in symmetrical fragments of HBP were usually different, the coefficient of asymmetry can be above, below, of equal to 1 and can be considered as a parameter of heterogeneity of the studied population (Table 1).

At the initial stage of systemic blood pressure decrease we observed a decrease in the amplitude of low-frequency harmonics in the blood flow spectrum on the left side (Fig. 1) and further decrease in systemic blood pressure was associated with predominance of respiratory rhythm harmonics (the amplitude was higher and the frequency was lower than on the right side). The dynamics of blood flow spectrum on the right side more markedly depended on the initial state: the amplitude of low-frequency harmonics increased when their initial values were low and vice versa (Fig. 1). Then, respiratory rhythm harmonics also predominated (less potent on the right side). On the left side, high positive correlations of MP and low-frequency harmonics in the blood flow spectrum were noted, on the right side these correlations were weak (Table 2), which reflected phasic nature of activity of these harmonics during blood flow decrease on the right side. The predominance of high-frequency harmonics in the spectrum is an indicator of passive mechanism of blood flow regulation [6,8]. When the amplitude of the respiratory rhythm harmonics in the spectrum is high, the phase picture is presented by an ellipse (Fig. 2). High amplitude of the respiratory rhythm in Doppler spectrum on the left side is an indicator of regular functioning, which is not typical of healthy systems [3].

Parameter S/ALF reflecting the tone of microvessels is the most important of derivative parameter calculated on the basis of spectral characteristics [6,8]. Changes in neuronal tonus of vessels on the left side were more pronounced (Table 3). With decreasing the systemic blood pressure this parameter characterizing the mean tone changed as 1:12.6:5.1 relative to the initial values. On the right side this parameter changed as 1:2.92:1.45. In all MCB, fragments with high and low vascular tone can be found, which is typical of heterogeneous

TABLE 1. Dynamics of MP in HBP Relative to Initial Values 30 min After Injections of Preparations ($M\pm\delta$)

Parameter	Initial	Start of pressure decrease (to 80% from the initial level)		Further pressure decrease (to 50% from the initial level)	
Left HBP	1	0.863±0.256	0.678±0.111	0.654±0.104	0.638±0.171
Right HBP	1	0.951±0.116	0.827±0.055*	0.810±0.073*	0.800±0.132*
Number of variances AC>1	15	8	10	7	12
AC<1	6	7	6	6	5
AC>1	1.373±0.354	1.601±0.534	1.241±0.280	1.302±0.222	1.147±0.118
AC<1	0.752±0.165	0.793±0.121	0.808±0.137	0.796±0.155	0.908±0.082

Note. AC: asymmetry coefficient, ratio of left to right MP. *$p\leq0.05$ for paired comparison (Student t test).

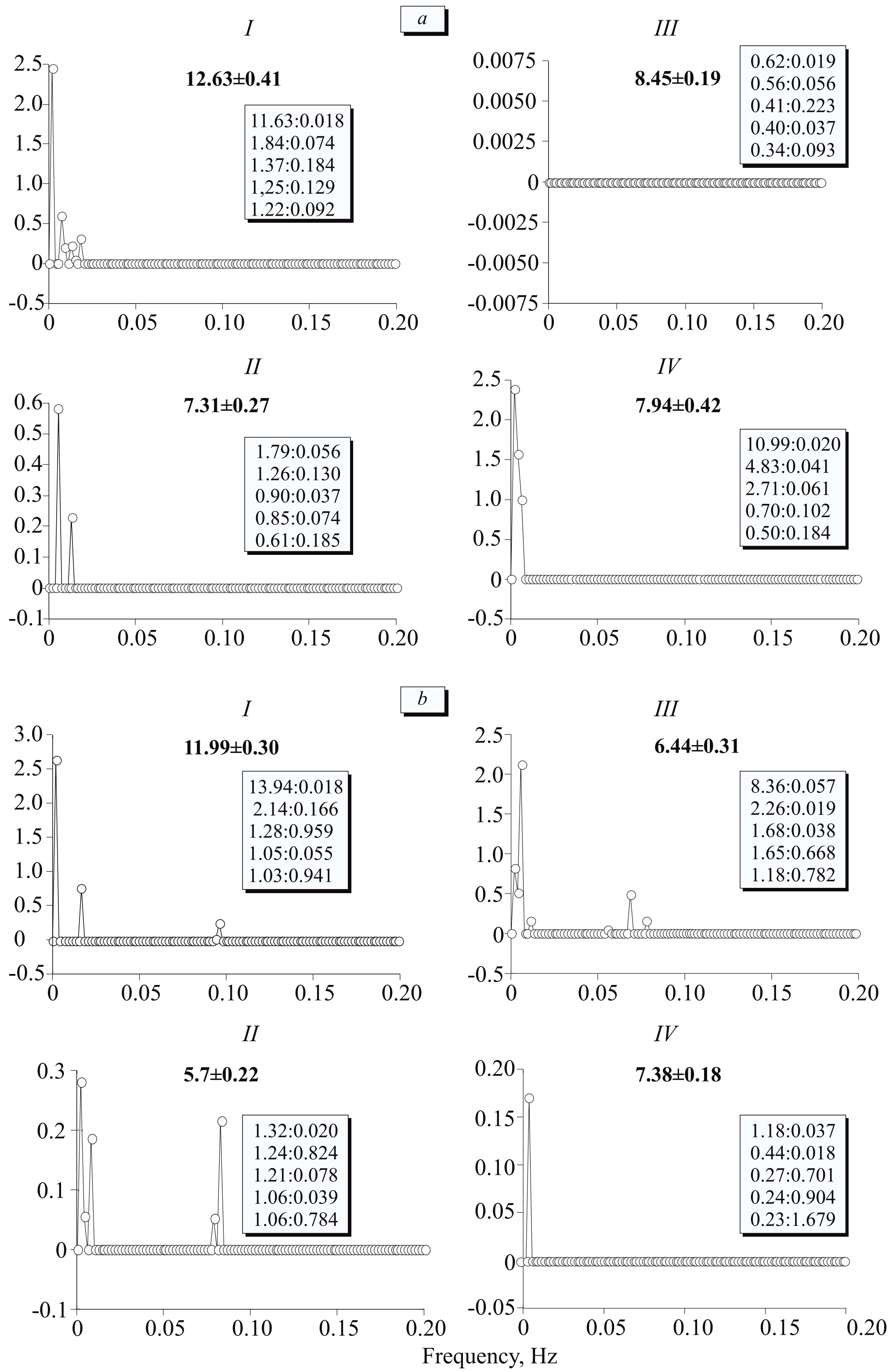

Fig. 1. Spectral characteristics of blood flow during the initial stages of blood pressure decrease in two hamsters (*a, b*). *I*: initial MP of the left HBP; *II*: MP of the left HBP during pressure decrease to 80%; *III*: initial MP of the right HBP; *IV*: MP of the right HBP during pressure decrease to 80%. Five dominant harmonics are presented; mean values are shown by bold figures. Ordinate: lg of harmonic amplitude.

TABLE 2. Correlation of MP with Amplitude of Low-Frequency Harmonics (Neurogenic amd Myogenic) and Vascular Tone during Blood Pressure Decrease ($M\pm\delta$)

Correlation	MCB on the left side	MCB on the right side
MP—neurogenic amplitude	0.910±0.132	0.399±0.281
MP—myogenic amplitude	0.731±0.256	0.185±0.199
MP—neurogenic tone	-0.521±0.111	-0.476±0.342
MP—myogenic tone	-0.453±0.271	-0.131±0.288
Neurogenic tone—myogenic tone	0.636±0.193	0.431±0.422

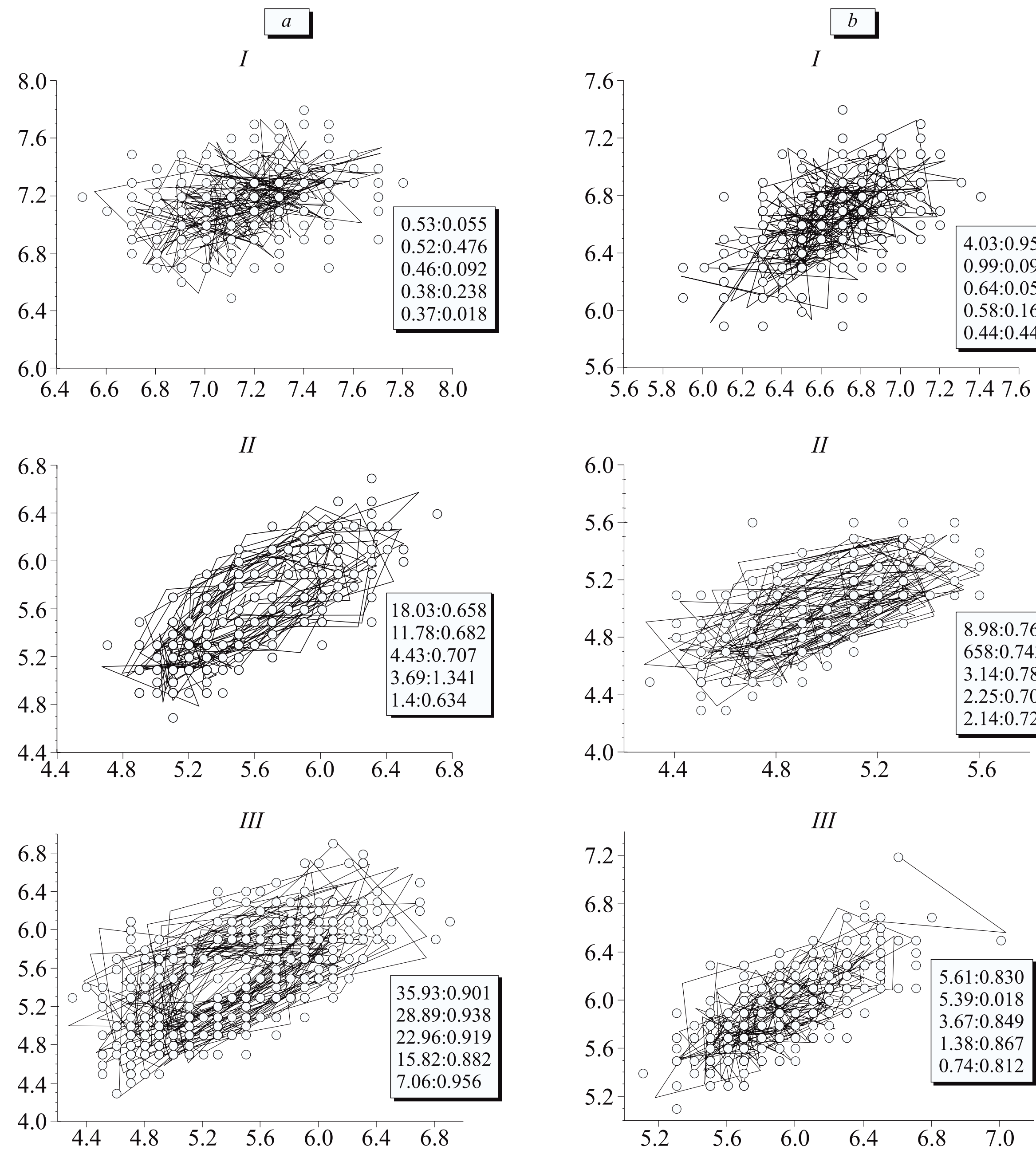

Fig. 2. Phasic blood flow picture in case of regular rhythm in Doppler spectrum during blood pressure decrease. *a*) MP of left HBP; *b*) MP of right HBP. *I*: initial; *II*: blood pressure drop to 80%; *III*: blood pressure drop to 50%. Five dominant harmonics are presented. Abscissa: MP in moment t; ordinate: MP in moment (t-1).

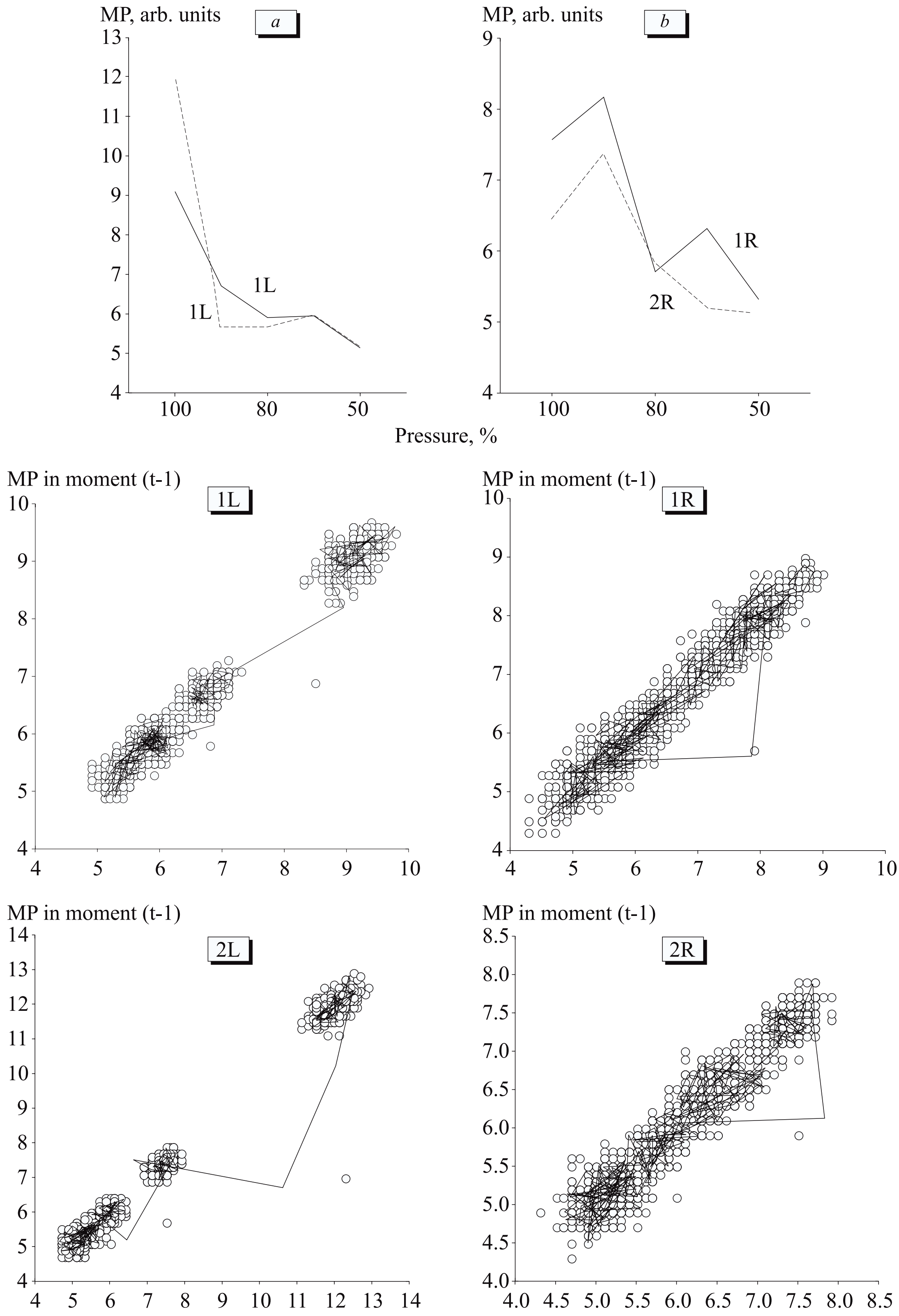

Fig. 3. Two types of transition during blood pressure decrease for two fragments of HBP on the left (*a*) and right side (*b*). Top plots: dynamics of MP changes; bottom plots: scatter plots of blood flow in HBP fragments.

TABLE 3. Parameter Characterizing Minimum Vascular Tone in the Dynamics of Systemic Pressure Decrease

Parameter	Fragments of circulatory bed	HBP on the left side			HBP on the right side		
Phase		I	II	III	I	II	III
Initial	N	0.034	0.053	0.021	0.303	0.083	0.038
	M	0.220	0.404	0.139	0.556	0.136	0.266
Pressure							
80% of initial	N	0.080	0.742	0.543	0.282	0.263	0.691
	M	0.300	0.471	0.708	0.632	0.296	0.548
50% of initial	N	0.184	0.074	0.296	0.389	0.156	0.068
	M	0.223	0.333	0.574	0.508	0.259	1.022
Maximum gradient of vascular tone	N	0.032—0.662—0.222			0.265—0.428—0.321		
	M	0.265—0.408—0.351			0.420—0.336—0.763		

Note. N: neurogenic tone, M: myogenic tone

systems. In the initial state, the maximum gradient of the neurogenic tone is higher on the right side, *i.e.* vessel distribution by the tone of MCB is heterogeneous on the right side. The increase in the maximum gradient of the neurogenic tone during the first phase of pressure decrease on the left side and myogenic tone at lower pressure values on the right side should also be noted. Different degree of heterogeneity is probably a factor of manifestation of two forms of transitions to a new state (Fig. 3 and Table 2): step-wise on the left side and continuous on the right side. Similar results were obtained in studies of the blood flow in the skin during inflammation [11]. The use of the method of high-frequency ultrasonic Doppler flowmetry for the evaluation of blood flow rate in individual microvessels [10] showed step-wise and continuous changes in blood flow rate under conditions mesenterial vessel occlusion and epinephrine application, respectively [15]. The type of transition is specific for MCB with different organization and for different pathological conditions, including paired organs and tissues, and probably affects the severity of disturbances in the system.

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