Pulsometric Study of the Functional State of Cardiovascular System under Conditions Provoking Neurogenic Syncopes

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The effects of passive and active orthostatic loads on the amplitude and temporal parameters of pulse waves were studied using an original computer assisted method of differential sphygmomanometry. Changes in the cardiac rhythm reflecting impairment of the autonomic regulation of the circulatory system and preceding neurogenic cardiovascular syncope were revealed and evaluated. Comparative analysis revealed similarity between these changes under conditions of both passive and active orthostasis, which confirmed the diagnostic value of differential sphygmomanometry.

Key Words: *pulse pressure; neurogenic cardiovascular syncope; diagnosis; vegetative regulation of blood circulation; orthostasis*

Neurogenic cardiovascular syncopes (NCVS) occupy an important place among acute pathological syncopes or short-term unconsciousness episodes. This group includes cardioinhibitory (neurocardiogenic) and vasodepressive (vaso-vagal) syncopes [1]. Sudden disturbances in the autonomic regulation of the blood circulation leading to changes in the heart rate (HR) and vascular tone are regarded as the pathophysiological basis of NCVS. The test with orthostatic load on an inclined table was proposed for studies of the mechanisms of this pathology [3]. However, this test is expensive and requires significant working area. These limitations were successfully surmounted after replacing passive orthostasis by its active version — standing up from lying to vertical position [2]. Therefore, it was reasonable to examine amplitude and temporal parameters (ATP) of the pulse under passive and active orthostatic load. The main purpose of the study was to reveal and evaluate the changes in pulse characteristics reflecting the impairment of the autonomic regulation of blood circulation during NCVS development. These studies promote elaboration and improvement of the methods of rational and objective diagnosis of NCVS patients. We assumed that despite the absence of NCVS precursor sympthoms, the syncope is preceded by increased tone of the sympathetic nervous system (tachycardia) followed by its paralytic attenuation and increased parasympathetic tone (bradycardia and/or vasodilation). These changes impair hemodynamics, decrease arterial pressure, and consequently lead to brain ischemia and loss of consciousness. Thus, revealing of the early signs of the impaired vegetative regulation of cardiovascular system is important and can be used as the basis for the study of peripheral mechanisms of NCVS development.

MATERIALS AND METHODS

The applied noninvasive computer method of pulsimetric diagnosis was elaborated at I. M. Sechenov Institute of Evolutionary Physiology and Biochemistry

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(IEPB). A piezoceramic transducer and an adapter performing an interface between the transducer and an IBM computer were used as technical basis of the method. The program performs recording, conversion, mathematical processing, and displaying of the results. This device provides simultaneous, quick, and simple registration and analysis of two main pulse characteristics, oscillations of arterial wall (recorded from digital and temporal arteries) and cardiac rhythm, which implies the novelty of the method compared to the routinely used techniques, *e.g.* electrocardiogram. The method provides the possibility of examining vegetative regulation of the cardiac rhythm as a common functional system.

The recorded differential sphygmogram reflects the rate of changes in pulse arterial pressure (PAP) at various stages of the cardiac cycle during the entire period of examination. In contrast to a single-wave curve of an ordinary sphygmogram, differential sphygmomanometry presents a cardiac cycle as a double-wave contour consisting of PAP and dicrotic pressure (DP) waves with typical bends. This allows precise analysis of cardiocycle ATP on the base of elaborated stable algorithm of isolation of encoding (calculated) points. This method allows to evaluate the following parameters of cardiovascular system activity: mean HR, mean and modal duration a standardized cardiac cycle (T_{NN} and Mo_{NN}), cardiointerval variability (SD_{NN}, CV_{NN}, VAR_{NN}, AMo_{NN}, and others), arrhythmia, PAP and its variability (SD_{PP}, CV_{PP}, and others), characteristics of the left ventricle myocardial contractility, as well as hemodynamic parameters including maximal rate of PAP increase (V_{max}), the time of blood ejection from the left ventricle, and others. PAP variability and the ratio between dicrotic and pulse waves (DP/PAP) reflect relative changes in the vascular tone.

The study included the test with passive orthostatic load [5] consisting in lifting a subject fixed on a table from lying to inclined (head up) position and active orthostasis test. Both tests caused similar changes in cardiac rhythm and hemodynamic parameters. In total, 24 subjects were examined. Group I consisted of the patients of St. Petersburg Institute of Cardiology examined on the occasion of NCVS manifestations. Testing of these patients included the following steps: after 30-min supine rest (control) the bed was inclined to 60° and the patients remained in this position until the development of syncope symptoms. Group II consisted of healthy 20-66-year-old volunteers (10 men and 10 women) without history of syncopes, who underwent active orthostatic test in IEPB: after 30-min supine rest (control) the subjects stood up and remained in vertical position for 25 min. In both groups, pulsogram recordings were started 5 min before lifting and continued to the end of examination. In all subjects, arterial pressure was measured several times during the last 10 min in lying position for calibration of recorded PAP. The results were processed statistically.

RESULTS

The study showed that the analysis of variability of PAP wave parameters combined with traditional analysis of cardiac rhythm variability can serve as an important additional method for examining vegetative regulation of the circulatory system. In both groups, orthostatic load caused significant changes in cardiac rhythm, pulse filling of the arteries, and their tone. In a group I man (aged 21) lifting was accompanied by HR acceleration and PAP decrease (by 37 and 70%, respectively, by min 5), while 6-7 min later it caused bradycardia, typical failure of the autonomic regulation of the vascular tone, and subsequent syncope development (zone of perverted high-amplitude oscillations on the pulsogram; Fig. 1, *a, b*). The impairment

TABLE 1. Pulse ATP in Patients Examined during Active Orthostasis (n=10)

Parameter	Lying position (control)		Standing position			
	5 min before standing up		5-10 min		15-20 min	
	W	M	W	M	W	M
HR, bpm	74	67	87**	85*	92**	82**
T_{NN}, sec	0.81	0.90	0.69**	0.71*	0.65**	0.73**
CV_{NN}, %	5.4	4.3	7.9	5.2	5.3	4.8
PAP, mm Hg	48	47	33**	31*	30**	32**
CV_{PAP}, %	7.0	5.3	12.5	9.0	13.9	11.0
V_{max}	593	499	605	450	515	447
DP/PAP	0.26	0.30	0.43*	0.64**	0.48*	0.41**

Note. *p<0.01, **p<0.05 compared to the corresponding control (Student's t test).

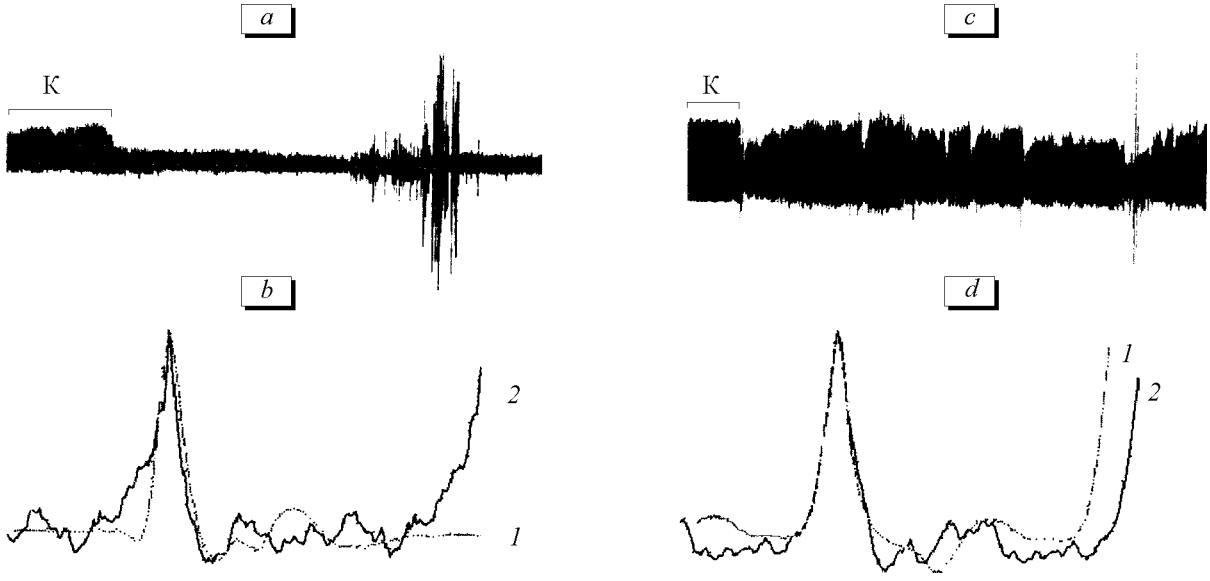

Fig. 1. Effect of orthostatic load (OL) on pulse arterial pressure (PAP) and vascular tone reflecting changes in vegetative regulation of blood circulation. *a*) time-compressed pulsogram of a man with typical changes in the regulation of PAP and vascular tone during passive OL. Left: control, lying position (*C*) then inclination (60°) inducing syncope; *b*) averaged cardiocycles of the same man in the lying (control, *1*) and inclined positions before syncope development (*2*); *c*) time-compressed pulsogram of a woman with typical changes in PAP and vascular tone during active OL. Left: control, lying position (*C*), then load, standing position; *d*) averaged cardiocycles of the same woman in the lying (control, *1*) and standing (*2*) positions.

of the autonomic regulation in this patient was manifested as typical peaks on the pulsogram reflecting spontaneous phase contractions of arterial myocytes caused by changes in the neurogenic component of the vascular tone (Fig. 1, *b*). The results of examination of other group I patients confirm the diagnostic value of neurocirculatory dystonia as a syncope precursor.

Active orthostatic load caused pulse ATP changes similar to those observed in group I patients. The type and magnitude of these changed varied depending on age and sex of the subjects. PAP and HR responses on gravitation load (Table 1) were most pronounced on min 5-10 and 15-20 in men and women, respectively. Elderly people showed minor changes, while young 20-25-year-old women demonstrated maximum changes, which were associated with minimum symptoms (asthenia, slight dizziness), and did not lead to bradycardia and syncope as in group I. In group II, a 20-year-old woman demonstrated short-term dizziness and typical impairment of the autonomic regulation of the vascular tone accompanied by abnormal high-amplitude oscillations on the pulsogram (similar to those in group I man) were observed on min 15 after lifting, however, syncope did not develop (Fig. 1, *c*). Similarity of curves *b* and *d* allows to regard active orthostatic test as a simple method for studying the dynamics and physiological mechanisms of NCVS. This is confirmed by the comparison between frequency spectra on pulsogram regions preceding the failure of the autonomic vascular regulation, as well as during this failure. Notably, syncope development (Fig. 1, *a*) or presyncope dizziness (Fig. 1, *c*) are associated with pulsogram perversion manifested as distortion of the double-wave contour and chaotic and dramatic increase in the amplitude. These changes reflect the impairment of the neurogenic component of the tone of skeletal muscles surrounding the artery subjected to pulsogram recording.

Thus, the applied modifications of the orthostatic test show similar results in revealing changes in frequency and pulse characteristics after functional load. These results agree with published data on the peculiarities of the autonomic regulation of the cardiac rhythm in patients subjected to similar conditions of passive and active orthostatic tests [2]. This confirms the diagnostic value of the proposed test for the integral evaluation of the circulatory system. The study revealed similar orthostatic load-induced changes in cardiac contractile activity and vascular tone in patients with a history of syncopes and in practically healthy subjects. However, in NCVS patients, these changes progressively develop, impair circulation, and lead to a syncope, while in healthy subjects they cause only transient changes followed by stabilization of the blood circulation. Further analysis of this phenomenon and the comparative study of orthostatic reactions in the patients and healthy individuals with the help of pulsometric method can improve the diagnosis of the functional state of cardiovascular system.

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