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FEATURES OF ELASTIC PROPERTIES OF VESSELS IN PATIENTS WITH ARTERIAL HYPERTENSION

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ABSTRACT

In recent years, it has been proven that the indicators of elastic properties of vessels may be considered as independent criteria of prognosis and efficiency of the treatment of cardiovascular diseases. All arterial beds are of potential interest for the study, as each of them has its own characteristics. The problem of connective tissue dysplasia, elastic properties of vessels is closely related to arterial hypertension, thereby, undifferentiated connective tissue dysplasia has a high prevalence in general population, especially among the young, working-age individuals. The main structural-functional characteristic of dysplasia is to reduce strength indices of the connective tissue with the increase of its elasticity, including the vascular wall.

The aim of the study was to identify patterns of changes in elastic properties of the elastic type vessels on the example of common carotid arteries in patients with arterial hypertension depending on the signs of connective tissue dysplasia.

A total of 54 patients (39 women, 15 men) with arterial hypertension aged 30-59 years were examined, who had elevated blood pressure of 2-3 degrees with high and very high added risk. The study of common carotid artery in the systole and diastole, intima-media complex, average maximum rate of blood flow to common carotid artery was performed using high-resolution sonography, as well as modules of Young and Peterson, coefficients of radial stress of the vessel wall, linear extensibility, stiffness index, local pulse wave velocity by common carotid artery were calculated.

Conducted study revealed, that the indicators of elastic properties of the common carotid arteries in hypertensive patients with signs of connective tissue dysplasia show less stiffness compared to patients without evidence of dysplasia. The differences in indicators of right and left common carotid arteries, which achieve reliable values for the quantities of coefficient of linear extensibility both in patients with arterial hypertension and signs of dysplasia and in their absence, were revealed.

Thus, based on the data of high-resolution sonography it can be concluded, that elastic properties of common carotid arteries in patients with arterial hypertension of II stage with signs of connective tissue dysplasia differ from those in patients without evidence of dysplasia, comparable by main clinical and demographic characteristics.

KEYWORDS: *hypertension, carotid arteries, elastic properties, connective tissue, dysplasia.*

INTRODUCTION

In recent years, it has been proven that the indicators of elastic properties of vessels may be considered as independent criteria of prognosis and efficiency of the treatment of cardiovascular diseases [*Gosse P et al., 2005; Laurent S et al., 2006; Willum-Hansen T et al., 2006; Recommendations of Ukrainian Association of Cardiologists, 2008; Sirenko Yu, Radchenko G, 2008*]. According to the recommendations of the European Association of Cardiologists for the prevention and treatment of arterial hypertension, it is recommended to explore the indicators characterizing the stiffness of blood vessels, in particular, the pulse wave velocity, as one of the criteria of target organ damage along with left

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ventricular hypertrophy, renal dysfunction, increased thickness of intima-media complex, microalbuminuria. Such recommendations are due to proven independent prognostic significance and the ability to use these indicators for the assessment of the overall risk of complications in arterial hypertension.

All arterial beds are of potential interest for the study, as each of them has its own characteristics. The determination of elastic properties of the aorta attracts the researchers, as it is known, that thoracic and abdominal aorta functions as buffering, and the increase of pulse wave velocity by the aorta is an independent predictor of adverse cardiovascular prognosis. However, other vascular regions also are of potential scientific interest [*Nikitin Yu, Lapitskaya I, 2005; Olejnikov V et al., 2009*]. It primarily relates to common carotid arteries, as they are most readily available for clinical studies. In determining elastic properties of the common carotid arteries, as a representative of vascular elastic type, it is important to take into account the fact, that its atherosclerotic changes are associated with increased risk of both stroke and other cardiovascular pathologies [*Mancia G et al., 2007; Eberth J et al., 2009*].

Since nowadays the evaluation of systemic arterial stiffness (for example the aorta) is determined by computational methods based on circulation models using a specially designed apparatus and is hindered in daily practice, the European experts proposed to measure regional and local arterial stiffness by directly noninvasive methods in different regions of the whole arterial tree. The main advantage of the regional assessment of elastic properties of vessels is that they are based on direct measurements of parameters that are closely connected with the direct stiffness of vessel walls [*Laurent S et al., 2006; Agafonov A, 2007; Aursulesei V et al., 2009*]. In recent years, significant changes were made in this direction in response to the widespread introduction of duplex scanning of vessels of high resolution, which allow studying the stiffness of vascular wall in details [*Tripoten M et al., 2011*]. For example, the studies of the thickness of intima-media complex of common carotid artery became a routine clinical practice. However, vascular sonography has a significantly greater potential than the study of the thickness of intima-media complex.

Experts from the European Society of Cardiology recommend using the following indicators of elastic properties of vessels [*O'Rourke M et al., 2002*; *Laurent S et al., 2006*]: coefficients of extensibility, ductility, modules of Young and Peterson. Experts pay great attention to ductility, extensibility, flexibility, elasticity and rigidity among the main properties of the vascular wall. The change in voltage of the vascular wall is considered as ductility [*Braunwald E, 2007; Haluska B et al., 2008*]. Extensibility of vascular wall depends on the vessel diameter ability to change in response to the changes of intravascular pressure. The stiffness is considered as reciprocal value before the extensibility. The elasticity of the vascular wall is directly related to its morphological structure [*Alessandri N et al., 2010*]. Elastic properties of vessels are determined by elastin, collagen and are sorted by located smooth muscle cells, the correlation of which is different in various regions of vascular beds. The content and relative positions of structural elements mainly determine the biomechanics of the vascular wall. Furthermore, it should be noted, that elastic properties of arteries are different and decrease from proximal more elastic vessels of large diameter to more rigid distal arteries. Undoubtedly, this is due to the structural features of arterial walls, which differ in different parts of the arterial tree [*McNulty M et al., 2006*].

Undifferentiated connective tissue dysplasia has a high prevalence in general population, especially among the young, working age individuals and it can affect the course of many diseases [*Rossiiskie rekomendatsii VNOK, 2009*]. The main structural-functional characteristic of undifferentiated connective tissue dysplasia is to reduce the strength indices of connective tissue with the increase of its elasticity, including the vascular wall. The problem of undifferentiated connective tissue dysplasia and elastic properties of vessels is closely related to arterial hypertension.

The aim of the study was to identify patterns of changes in elastic properties of vessels of elastic type on the example of common carotid artery in patients with arterial hypertension depending on the signs of undifferentiated connective tissue dysplasia.

Material and methods

A total of 54 patients (39 women, 15 men) with arterial hypertension aged 30-59 years were examined, who had elevated blood pressure of 2-3 degrees with high and very high added risk. Hypertensive patients with signs of undifferentiated connective tissue dysplasia were involved in I group (n=34), and patients without signs of dysplasia – in II group (n=20). Exclusion criteria were the presence of endocrine disease, coronary heart disease, congestive heart failure, chronic kidney disease, severe obesity, resistant hypertension. Arterial hypertension was diagnosed according to the recommendations of the Ukrainian Association of Cardiology for the prevention and treatment of arterial hypertension (2008), and undifferentiated connective tissue dysplasia – in identifying at least 6 phenotypic and/or visceral criteria of dysplasia in the patient, after excluding of its syndromes, that can be classified [*Rossiiskie rekomendatsii VNOK, 2009; Smolnova T, 2009*]. The diameter of common carotid artery in the systole and diastole, the thickness of intima-media complex, average maximum rate of blood flow to common carotid artery was studied using high-resolution sonography on the machine LOGIQ 5 ("General Electric Medical Systems", USA) by multifrequency sensor in the range of 3-12 *MHz*. Modules of Young and Peterson, coefficients of radial stress of the vessel wall, linear extensibility, stiffness index, the local pulse wave velocity by common carotid artery were also calculated [*Agafonov A, 2007*].

Statistical analysis of the study results was done using the software package "STATISTICA® for Windows 6.0" with the use of parametric and non-parametric methods to estimate the significance of differences (Student t-test, Mann-Whitney, Wilcoxon, Pearson, Fisher's exact test) and correlation analysis. Statistical indicators are presented in the form of: the number of observations (n), the arithmetic mean (M), standard error of the mean (m), Spearman coefficient of rank correlation (r). The critical significance level was taken $p<0.05$, the tendency was determined at $p<0.01$.

Results and discussion

The differences were identified while comparing groups of patients based on morphometric parameters and indicators of elastic properties of common carotid arteries (Table 1). Significant differences of indicators such as modules of Peterson ($p<0.05$) and Young ($p<0.05$), linear extensibility ($p<0.01$), stiffness index ($p<0.05$) and local pulse wave velocity by common carotid artery ($p<0.05$) were established. At the same time, no significant differences between the parameters of the radial wall stress were established in examined patients.

Thus, it was established, that the indicators of elastic properties of common carotid artery in hypertensive patients with signs of undifferentiated connective tissue dysplasia are shifted towards the reduction in rigidity.

Differences of studied parameters of right and left common carotid arteries in patients of both

Table 1

Indicators of elastic properties of common carotid artery in patients with arterial hypertension (M±m)

Indicators	Right common carotid artery		Left common carotid artery	
	I group (n=34)	II group (n=20)	I group (n=34)	II group (n=20)
Thickness of intima-media complex (*mm*)	0.78±0.04	0.89±0.04*	0.82±0.03	0.90±0.03*
Peterson's modulus, (*mm Hg*)	442.01±31.27	547.63±33.33*	467.41±33.11	582.62±31.23*
Coefficient of radial stress of vascular wall (*c.u.*)	0.13±0.01	0.11±0.01**	0.12±0.01	0.10±0.01**
Coefficient of linear extensibility (*c.u.*)	0.0023±0.0002	0.0018±0.0002**	0.0021±0.0002	0.0017±0.0002**
Young's modulus (*mm Hg*)	1503.9±119.4	1838.1±114.2*	1589.1±121.9	1931.8±118.7*
Stiffness index (*c.u.*)	4.19±0.29	4.93±0.23*	4.49±0.33	5.41±0.28*
Local pulse wave velocity (*m/s*)	5.17±0.18	5.76±0.22*	5.32±0.18	5.93±0.24*

Note: *the differences between the indices of I and II groups are valid: * – $p<0.05$; ** – $p<0.01$.*

groups were revealed. Differences in the coefficients of linear extensibility from the left and right reach significant values ($p<0.05$), which is explained by anatomical features of vessels. The right common carotid artery originates from the brachiocephalic trunk, and the left – directly from the aortic arch. Due to this the left common carotid artery is a few centimeters longer than the right one [*Sinelnikov R et al., 2008*]. That's why the rate of blood flow and vascular properties differ, which is important to take into account while comparing the indicators of various studies.

The dependence of the indicators of elastic properties of common carotid artery on the rate of increase in blood pressure in hypertensive patients with and without signs of undifferentiated connective tissue dysplasia was studied (Table 2). The differences between the values of the thickness of intima-media complex in patients with 2-3 degrees of blood pressure increase with signs of undifferentiated connective tissue dysplasia and patients without signs of dysplasia and Peterson modulus on the left common carotid artery in patients with 3rd grade increase in blood pressure were revealed ($p<0.05$).

According to the correlation analysis direct links with both sides of Peterson's modulus ($r=+0.35$), stiffness index ($r=+0.36$) and local pulse wave velocity by common carotid artery ($r=+0.35$) with thickness of intima-media complex ($p<0.05$) and feedbacks of Young's modulus ($r=-0.28$), coefficient of radial stress ($r=-0.35$) and linear extensibility ($r=-0.37$) and IMC ($p<0.05$) were established in hypertensive patients with signs of undifferentiated connective tissue dysplasia. Feedbacks of Young's modulus ($r=-0.38$) and the coefficient of radial wall stress ($r=-0.38$) with thickness of intima-media complex ($p<0.05$) are determined in hypertensive patients with no signs of undifferentiated connective tissue dysplasia. Such directions of correlation between the studied parameters could be expected. Thickness of intima-media complex results in a significant increase in the rigidity of vessels, in consequence of which direct links are established between its indicators of increased rigidity, and feedbacks with indicators of elasticity. It should be stated that the correlations in hypertensive patients with and without symptoms of undifferentiated connective tissue dysplasia differ. It can be concluded that the mechanisms of change in elastic properties of common carotid artery in the examined groups of patients are different, which again confirms that different mechanisms of development and course are specific for arterial hypertension.

To confirm this hypothesis, a correlation analysis was performed between the indicators of elastic properties of vessels in both groups, with the average maximum speed of blood flow in the left and right common carotid arteries. Thus, reliable strong feedbacks of average maximum velocity of blood flow in the left common carotid artery with a diameter of the left common carotid artery in systole ($r=-0.71$, $p<0.05$) and diastolic

TABLE 2.

Indicators of elastic properties of common carotid artery in hypertensive patients depending on the degree of blood pressure increase (M±m)

Indicators		hypertension of II stage		hypertension of II stage	
		I group (n=17)	II group (n=8)	I group (n=17)	II group (n=12)
Thickness of intima-media complex (mm)		0.81±0.03	0.88±0.02*	0.80±0.03	0.91±0.04*
Young's modulus (mm Hg)	Right	1455.3±160.3	1421.3±162.1	1692.7±204.1	2160.9±478.9
	Left	1528.5±162.5	1325.9±191.6	1785.1±212.3	2439.8±276,6
Peterson's modulus (mm Hg)	Right	424.4±40.7	432.9±42.1	480.1±48.6	578.7±113.1
	Left	447.9±44.2	432.9±65.6	503.8±48.1	699.8±80.8*

Note: the differences between the indices of I and II groups are valid, * – $p<0.05$.

(r=-0.77, p<0.05) and reliable feedbacks medium strength averaged maximum velocity of blood flow in the right common carotid artery with the diameter of right common carotid artery in systole (r=-0,52, p<0.05) and diastolic (r=-0.62 , p<0.05) were established in the group of patients with hypertension without evidence of undifferentiated connective tissue dysplasia. Correlation dependence has not been established between the indicators of elastic properties of common carotid artery and the average maximum speed of blood flow in common carotid artery on both sides in the group of patients with signs of undifferentiated connective tissue dysplasia. This can be explained by the fact that the reduction of common carotid artery diameter in patients without signs of dysplasia leads to the increase of the linear velocity of blood flow through it, in accordance with the basic postulates of physical hydrodynamics. In case of the presence of connective tissue dysplasia, when the structure of circular fibers of elastic vessels is disturbed, such dependency is not detected, i.e. the reduction of the vessel diameter does not lead to an increase in the average maximum blood flow velocity over it. The differences in indicators of right and left common carotid arteries, which achieve reliable values for the quantities of coefficient of linear extensibility both in patients with arterial hypertension and signs of dysplasia and in their absence, were revealed.

According to sonography data it was established, that elastic properties of common carotid artery in patients with arterial hypertension of II stage with and without signs of undifferentiated connective tissue dysplasia differ from each other and are comparable to main clinical and demographic characteristics. Indicators of elastic properties of common carotid artery of studied hypertensive patients with signs of undifferentiated dysplasia demonstrated less stiffness relative to those in patients without signs of dysplasia.

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