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Сосудистая жесткость у пациентов старческого возраста с хронической сердечной недостаточностью

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АННОТАЦИЯ

Введение. Изучение сосудистой жесткости является методом оценки риска сердечно-сосудистых заболеваний. Одним из методов оценки артериальной жесткости является сердечно-лодыжечный сосудистый индекс (англ.: *cardio-ankle vascular index*, CAVI), отражающий степень структурных поражений сосудов. Данный индекс перспективен для изучения сосудистой жесткости у лиц старческого возраста с хронической сердечной недостаточностью (ХСН) с целью выявления новых предикторов сердечно сосудистого риска.

Цель. Изучение индексов сосудистой жесткости (сердечно-лодыжечного и лодыжечно-плечевого) у пациентов старческого возраста (75–89 лет) с ХСН методом объемной сфигмографии.

Материалы и методы. В исследование включено 120 пациентов (87 женщин и 33 мужчины) с ХСН старческого возраста (средний возраст 81,3 ± 4,2 лет). Всем пациентам проводился анализ показателей эхокардиографии и сфигмографии с оценкой индекса CAVI и лодыжечно-плечевого индекса.

Результаты. У пациентов с ХСН IV функционального класса (ФК) наблюдался наибольший индекс CAVI справа, который превышал показатели групп ХСН II ФК и III ФК на 0,57 и 1,02 единиц соответственно ($p < 0,05$). Индекс CAVI слева был выше у пациентов с ХСН IV ФК по сравнению с группами ХСН II ФК и III ФК (на 0,47 и 0,6 единиц соответственно, $p < 0,05$). Также были выявлены корреляционные взаимосвязи сосудистой жесткости с возрастом пациента, ФК ХСН и с эхокардиографическими показателями: фракцией выброса левого желудочка, конечным диастолическим размером левого желудочка, конечным систолическим размером левого желудочка ($p < 0,05$).

Заключение. Сердечно-лодыжечный сосудистый индекс может использоваться для оценки сосудистой жесткости у пациентов старческого возраста с ХСН и может помочь определить риск сердечно-сосудистых заболеваний. Необходимы дальнейшие исследования на большей выборке пациентов.

Ключевые слова: *сердечно-лодыжечный сосудистый индекс; хроническая сердечная недостаточность; лодыжечно-плечевой индекс*

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Vascular Stiffness in Senile Patients with Chronic Heart Failure

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ABSTRACT

INTRODUCTION: The study of vascular stiffness is a method of assessing the risk of cardiovascular diseases. One of methods of assessing arterial stiffness is thecardio-ankle vascular index (CAVI), which reflects the extent of structural lesion of vessels. This index has prospects in application for studying vascular stiffness in senile individuals with chronic heart failure (CHF) to identify new predictors of the cardiovascular risk.

AIM: To study the parameters of vascular stiffness (cardio-vascular and ankle-brachial indices) in senile patients (75–89 years) with CHF using the volume sphygmography method.

MATERIALS AND METHODS: The study included 120 patients (87 women and 33 men) with CHF of senile age (mean age 81.3 ± 4.2 years). In all patients, the electrocardiography and sphygmography data were analyzed with assessment of the CAVI and ankle-brachial index.

RESULTS: In patients with IV functional class (FC) CHF, the highest CAVI was found on the right exceeding the parameters of II FC CHF and III FC CHF groups by 0.57 and 1.02 units, respectively ($p < 0.05$). The CAVI on the left in patients with IV FC CHF was higher in comparison with II FC CHF and III FC CHF groups by 0.47 and 0.6 units, respectively. There were also identified correlation relationships of vascular stiffness with the age of patients, functional class of chronic heart failure and echocardiographic parameters: left ventricle ejection fraction, left ventricle end-diastolic diameter, left-ventricle end-systolic diameter ($p < 0.05$).

CONCLUSION: The cardio-ankle vascular index can be used to assess vascular stiffness in senile patients with CHF and can help determine the risk of cardiovascular diseases. Further studies are needed on a larger sample of patients.

Keywords: *cardio-ankle vascular index; chronic heart failure; ankle-brachial index*

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LIST OF ABBREVIATIONS

ABI — ankle-brachial index
AP — arterial pressure
CAVI — cardio-ankle vascular index
CHF — chronic heart failure
CVD — cardiovascular disease
EDD — end diastolic diameter
EF — ejection fraction
ESD — end systolic diameter
FC — functional class
L — on the left
LV — left ventricle
R — on the right

INTRODUCTION

Age is an established risk factor for development of cardiovascular diseases (CVD), however, vascular changes considerably vary in individuals of the same age group, and the *vascular health* parameters are increasingly recognized to have a better prognostics value for adverse cardiovascular outcomes than the *passport age* [1–3].

Ageing is associated with morphological changes in all layers of the vessel wall. They include thickening of the arterial wall even in the absence of athero-sclerotic disease. These changes lead to an increase in vascular stiffness, in central arterial pressure (AP), in systolic pressure and pulse pressure with a decrease in diastolic blood pressure [1]. Endothelial dysfunction and a decrease in the elasticity of the vessel wall, irrespective of coronary atherosclerosis, cause the development of such cardiovascular catastrophes as myocardial infarction [2, 3].

Volume sphygmography indices are used to assess the primary and secondary prevention of CVD [4, 5]. Determining the pulse wave velocity in the area from the common carotid artery to the femoral artery is the 'gold standard' for measuring arterial stiffness.

Currently, there exist methods, in particular, the assessment of the cardio-ankle vascular index (CAVI), which, according to the data of numerous epidemiological and clinical studies, is of independent diagnostic and prognostic significance [6]. It was found at the population level that the CAVI index slowly changes over time, therefore it is not sensitive to modification of risk factors or pharmacological interventions [7]. The accumulated data on volume sphygmography show that arterial stiffness and CAVI correlate with atherosclerotic load and are predictors of CVDs [7, 8].

In the conducted longitudinal studies, a decrease in CAVI by more than 0.15 units over three years is associated with 2.4 times higher risk of death and 2.8 times higher mortality from CVDs [8–10]. In some studies, an association was found between CAVI > 9 units and an increased risk of CVDs, while in other studies CAVI > 8 units was reported to be a risk factor for cardiovascular catastrophes [11, 12].

According to the materials of the ESSE-RF study, the arterial stiffness index in the adult population sample of Tomsk, had an independent prognostic significance for CVD, and the index more than 7.8 units was a reclassifies of cardiovascular risk [13]. In other studies of CVDs, CAVI below 7.8 units compared with that above 7.8 units correlated with a higher risk of developing chronic heart failure (CHF) in patients without coronary heart disease (odds ratio 1.61, 95% confidence interval 1,14–2,29) [7, 14]. Currently, CAVI is used to predict mortality from CVDs (coronary heart disease, stroke) [15].

The **aim** of this study vascular stiffness indices in senile patients with chronic heart failure using volume sphygmography.

MATERIALS AND METHODS

The study protocol was considered and approved by the Local Ethics Committee of Ryazan State Medical University (Protocol No. 3 of October 10, 2021).

Inclusion criteria: (1) CHF diagnosis stated in the medical card, (2) patient's age corresponding to senility in WHO classification (75–89 years), (3) life expectancy more than a year, (4) signing the Informed consent to participation in the study.

Exclusion criteria: (1) age of long-livers (≥ 90 years), (2) a documented active oncological process, (3) signs of acute inflammation including the new coronavirus infection, (4) clinically significant exacerbation of a chronic disease except CHF, (5) a severe mental illness.

Echocardiographic examination was performed on a Philips Affinity 70 apparatus of expert class (Phillips Corp., the Netherlands), with the assessment of linear dimensions of heart chambers, left ventricular (LV) ejection fraction (EF), and condition of heart valves.

Using a Vasera VS-2000 volume sphygmography apparatus (Fukuda Denshi Corp., Japan), vascular stiffness was assessed including CAVI (a parameter of rigidity of the aorta and arterial vessels, an estimate of the pulse wave velocity and vessel wall elasticity), and ankle-brachial index (ABI) that reflects the ratio of systolic AP measured on the shin to that measured on the brachial artery, demonstrates the degree of stenosis/occlusion in the system of the popliteal artery)).

The study involved 120 patients (87 women (72.5%) and 33 men (27.5%)) of senile age (mean age 81.3 ± 4.2 years) with CHF.

In the studied cohort of patients, arterial hypertension was recorded in 99% of cases, coronary heart disease — in 70% (including a past myocardial infarction in 26%), type 2 diabetes mellitus — in 18.3%, aortic stenosis — in 19%, mitral stenosis — in 3.5%, a complete block of the left branch of the bundle of His — in 21%, a complete block of the right branch of the bundle of His — in 7.5%. Ten percent of patients had a history of coronary artery stenting, 53% — of atrial fibrillation, and 13% — of acute cerebrovascular accident.

The mean height of the studied patients was 163.09 ± 7.86 cm, the mean body weight — 75.18 ± 13.36 kg, the mean body mass index — 28.26 ± 4.76 kg/m^2, the mean waist circumference — 99.80 ± 11.51 cm, the mean body surface area — 1.80 ± 0.18 m^2, the mean systolic AP — 147.8 ± 23.5 mm Hg, the mean diastolic AP — 84.6 ± 12.3 mm, the mean pulse pressure — 63.6 ± 20.0 mm Hg.

The distribution of patients by CHF stages was as follows: 10% had I stage of the disease, 73% — IIA stage, 17% — IIB stage; stage III was not recorded. On inclusion in the study, 1.2% of patients had the first functional class (FC) of CHF, 52.2% — II FC, 44.2% — III FC, 2.4% — IV FC. LVEF was preserved in 78% of cases, moderately reduced in 12%, low in 10%. Signs of CHF decompensation upon admission to hospital were recorded in 41% of patients.

The data analysis was carried out using the Stat Soft 13.0 program (Dell Inc., USA). The Kolmogorov–Smirnov test was used to assess the normality of the distribution of the quantitative data. The data are presented as a mean value (M) and a standard deviation (SD). Single-factor analysis of variance was used to compare the mean values, and the probable relationship between variables was assessed using linear regression analysis. The differences were considered statistically significant at $p < 0.05$.

RESULTS

Depending on the FC of CHF, the patients were divided into three groups (Table 1). As follows from the table data, the CAVI on the right (R) in patients with II FC CHF was statistically higher by 0.45 units than in patients with III FC CHF (p = 0.04). The highest R-CAVI was identified in IV FC CHF group, where it was 0.57 units higher than in II FC CHF and 1.02 units higher than in III FC CHF group (p = 0.035 and p = 0.041, respectively).

In comparison, ABI on the right was comparable in the group of patients with II FC CHF and III FC CHF, but differed from the group of patients with IV FC CHF by 0.37 units (p = 0.05 and p = 0.04, respectively). CAVI on the left was 0.47 units higher in patients with IV FC CHF in comparison with patients with II FC CHF and 0.6 units higher than in patients with III FC CHF (p = 0.021 and p = 0.03, respectively). ABI on the left was statistically significantly lower by 0.15 units and by 0.34 units in the group of patients with IV FC CHF relative to the groups with II FC CHF and III FC CHF (p = 0.034 and p = 0.043, respectively).

Linear regression analysis revealed statistically significant interrelations of the functional class of CHF with the indices:

- R-CAVI (B = 9.316 (8.814; 9.818); p = 0.001, R^2–0.02);
- R-ABI (B = 1.361 (1.071; 1.652); p = 0.001. R^2–0.16);
- L-CAVI (B = 9.718 (9.266; 10.170); p = 0.001. R^2–0.001);
- L-ABI (B = 1.065 (0.839; 1.291); p = 0.001. R^2–0.001).

Besides, statistically significant interrelations of the patients' age with R-ABI (B = 4.267 (0.693; 7.841); p = 0.020, R^2–0.014) were also recorded.

Depending on the value of CAVI and taking into the account the literature data [1], the patients were divided into two groups: ***group 1*** involved patients with the CAVI below 7.8 units ('normal' vessels), ***group 2*** included patients with the CAVI more than 7.8 units ('stiff' vessels). Comparative assessment of the heart ultrasound parameters of the patients with CHF depending on the degree of vascular stiffness (Table 2) was carried out.

Patients of ***group 2*** ('stiff' vessels) had a larger diameter of the left atrium at rest (by 0.1 cm, p = 0.006), a higher LFEF (by 4.4%, p = 0.045), thickness of the posterior wall of the LV in diastole (by 0.02 cm, p = 0.05), whereas patients of ***group 1*** ('normal' vessels) had a larger end-diastolic diameter (EDD) of the LV (by 0.12 cm, p = 0.005), end-systolic diameter (ESD) of the LV (by 0.27 cm, p = 0.045), thickness of the interventricular septum (by 0.03 cm, p = 0.046), anteroposterior dimension of the right ventricle (by 0.22 cm, p = 0.05).

Statistically significant differences were recorded between group 1 and group 2 in the anteroposterior dimension of the right ventricle, both in R-CAVI and L-CAVI subgroups (p = 0.004 and p = 0.044, respectively).

Linear regression analysis revealed statistically significant interrelations of the LVEF with the indices:

- R-CAVI (B = 7.253 (5.626; 8.880); p = 0.001. R^2–0.039);
- L-CAVI (B = 8.154 (6.713; 9.595); p = 0.001. R^2–0.024);
- L-ABI (B = 1.452 (0.659; 2.244); p = 0.001. R^2–0.004).

Statistically significant correlations were recorded between the EDD LV and indices:

Table 1. Comparative Characteristics of Volume Sphygmography Indices in Patients Depending on Functional Class of Chronic Heart Failure

Index		Index Value, units			p
		chronic heart failure, II functional class	chronic heart failure, III functional class	chronic heart failure, IV functional class	
		1	2	3	
On the right	R-CAVI	9.63 ± 1.68	9.18 ± 2.96	10.2 ± 0.85	p_{1-2} = **0.04** p_{1-3} = **0.035** p_{2-3} = **0.041**
	R-ABI	1.17 ± 1.27	1.17 ± 1.51	0.80 ± 0.07	p_{1-2} = 0.6 p_{1-3} = **0.05** p_{2-3} = 0.4
On the left	L-CAVI	9.73 ± 1.53	9.60 ± 2.67	10.2 ± 1.14	p_{1-2} = 0.71 p_{1-3} = **0.021** p_{2-3} = **0.03**
	L-ABI	1.02 ± 0.16	1.21 ± 1.56	0.87 ± 0.13	p_{1-2} = **0.05** p_{1-3} = **0.034** p_{2-3} = **0.043**

Notes: L-ABI — ankle-brachial index on the left, L-CAVI — cardio-ankle vascular index on the left, R-ABI — ankle-brachial index on the right, R-CAVI — cardio-ankle vascular index on the right

Table 2. Parameters of Echocardiography in Normal and Increased Value of Cardio-Ankle Index

Parameters	On the right			On the left		
	≥ 7,8 ед.	< 7,8 ед.	p	≥ 7,8 ед.	< 7,8 ед.	p
Left atrium, cm	4,53 ± 0,66	4,43 ± 1,61	***0,006***	4,54 ± 0,68	4,42 ± 1,50	***0,08***
End-diastolic diameter of the left ventricle, cm	5,18 ± 0,76	***5,30 ± 0,51***	***0,005***	5,19 ± 0,76	5,25 ± 0,53	***0,031***
End-systolic diameter of the left ventricle, cm	3,59 ± 0,90	3,86 ± 0,70	***0,045***	3,59 ± 0,90	3,86 ± 0,70	***0,03***
Left ventricular ejection fraction, %	56,57 ± 11,95	52,17 ± 11,57	***0,045***	56,43 ± 11,96	53,31 ± 11,87	*0,07*
Interventricular septum thickness, cm	1,13 ± 0,15	1,15 ± 0,23	***0,005***	1,12 ± 0,14	1,14 ± 0,26	*0,055*
Posterior left ventricular wall thickness, cm	0,99 ± 0,13	0,97 ± 0,16	*0,05*	0,99 ± 0,12	0,99 ± 0,17	*0,05*
Anteroposterior dimension of the right ventricle, см	2,56 ± 0,35	2,78 ± 0,40	***0,004***	2,56 ± 0,35	2,72 ± 0,44	***0,044***

- R-CAVI (B = 10.154 (7.662; 12.646); p = 0.001. R^2–0.002).
- L-CAVI (B = 10.192 (8.001; 12.382); p = 0.001. R^2–0.002).

Statistically significant correlations were identified between the ESD LV and indices:

- R-CAVI (B = 10.285 (8.814; 11.756); p = 0.001. R^2–0.009);
- R-ABI (B = 1.373 (0.458; 2.289); p = 0.004. R^2–0.001);
- L-CAVI (B = 10.671 (9.382; 11.959); p = 0.001. R^2–0.015).

DISCUSSION

Arterial stiffness is a significant risk factor for the heart failure [16]. To note, besides predictive function, vascular stiffness parameters can also be used to select antihypertensive therapy and can become the target for novel or already existing drugs, which means that *correction of vascular stiffness may help reduce cardiovascular mortality* [17].

CAVI is a promising parameter in the assessment of arterial stiffness, the data on its clinical significance have been already accumulated, and *one of its advantages is independence of AP* [18].

A group analysis in our study showed that *an increase in the arterial stiffness was in correspondence with increasing severity of CHF*; increased arterial thickness has an effect on the post load of the LV which predisposes to its hypertrophy and is an independent predictor of cardiovascular death [8].

In the assessment of R-IV and L-ABI in the group of IV FC CHF, lower values of these indices were noted, which may evidence *a high probability for stenosis or occlusion in the system of the femoral and popliteal arteries*.

Statistically significant interrelations between the patient's age and ABI were recorded, the values of the latter were statistically significantly higher in patients with IV FC CHF. Statistically significant interrelations of CHF with R-CAVI, R-ABI, L-CAVI, L-ABI *may evidence an association between vascular stiffness and development of CVD*. The data obtained by us are confirmed in recent studies that reflect the predictive potential of CAVI [19, 20].

Assessment of the US parameters of the heart showed statistically higher linear dimensions of the left atrium, higher values of thickness of the posterior wall of the LV and higher LVEF in the group with 'stiff' vessels, which, in our opinion, reflects a history of arterial hypertension with damage to the heart as the target organ.

In linear regression analysis, the LVEF echocardiographic parameter appeared to be most *dependent on the age-related vascular stiffness and occlusion*. The EDD LV and ESD LV echocardiographic parameters depended only on vascular stiffness. More accurate conclusions about the vascular stiffness in senile patients with CHF can be made in the course of in-depth studies on a larger cohort of patients.

CONCLUSION

The results of measuring the cardio-ankle vascular index reflecting the elastic properties of blood vessels, revealed higher vascular stiffness in patients with chronic heart failure of IV functional class and a high risk for occlusion in the femoral-popliteal vascular system, especially on the left, compared with lower functional classes of chronic heart failure.

The cardio-ankle vascular index showed a statistically significant correlation with the patient's age and with echocardiographic parameters (left ventricular ejection fraction, end systolic and end diastolic dimensions of the left ventricle). The effect of vascular stiffness on the dilatation of the left atrium and right ventricle was identified. The existence of peripheral artery diseases and a reduced left ventricular ejection fraction are probably associated with a limited exercise tolerance and impaired cardiopulmonary function, which is a potential mechanism for increased risk of cardiovascular diseases.

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