**Diastolic Function of the Left and Right Ventricles of the Heart in Outpatients with Arterial Hypertension**

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The aim of the study is to investigate the impairment of diastolic function of the left ventricle (LV) and the right ventricle (RV) in arterial hypertension outpatients.

**Materials and methods**. Arterial hypertension patients (n=299) and practically healthy people (n=62) were examined on an outpatient basis. Echocardiographically, diastolic dysfunctions of both ventricles were evaluated.

**Results**. All the arterial hypertension patients had a pattern of diastolic dysfunction (DD) of the RV of different grades (grade I RVDD and grade II RVDD), regardless of the presence or absence of pulmonary arterial hypertension. Patterns of grade I LVDD and grade I RVDD were detected in 84 patients. Patterns of grade I LVDD and grade II RVDD were detected in 77 patients. Patterns of grade II LVDD and grade II RVDD were detected in 41 patients. A pattern of grade II RVDD with normal left ventricular diastolic function was detected in 97 patients with a short duration of disease (3.92±0.48 years) versus the other groups with more than 15 years of hypertension. 175 arterial hypertension patients had grade I or II LVDD only in 18.3% of cases according to the recommendations of the American and European societies of echocardiographers (2016).

**Conclusion**. The patients with a short period of hypertensive disease have only the pseudonormal pattern of RVDD, which can be an early diagnostic marker of heart failure. Echocardiographic diagnosis of diastolic function made according to various criteria can both increase the number of chronic heart failure patients and significantly decrease it.

**Keywords**: diastolic dysfunction, right ventricle, left ventricle, arterial hypertension, chronic heart failure

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**Introduction**

Cardiovascular diseases lead to the development of diastolic and/or systolic left ventricular heart failure resulting in pulmonary arterial hypertension, which causes the development of right ventricular heart failure. It is generally accepted that pulmonary arterial hypertension participates in the pathogenesis of right heart failure; the development of pulmonary arterial hypertension, regardless of its causes, leads to overload of the right heart [1].

However, there is some evidence that the impairment of the diastolic function of the right ventricle is a common situation in patients with chronic heart failure; it is also detected in cases of normal pressure in the pulmonary artery [2, 3]. In different studies, the incidence of diastolic dysfunction (DD) of the right ventricle varies depending on the research methods and groups of subjects. In patients with hypertension, the incidence of diastolic dysfunction of the right ventricle is about 33%, and this was exhibited under the following conditions: E/A of the tricuspid valve ranged from 0.8 to 2.1, E/e'>6, e'/a'<0.6 [4]. In patients with ischemic heart disease, the use of longitudinal analysis revealed an impairment of the diastolic function of both ventricles in all the examined patients. The diastolic dysfunction of the left and right ventricles was of different types [5]. According to Doppler echocardiography performed in pulse and colour modes in patients with arterial hypertension, the left ventricular relaxation disorder was accompanied by normal diastolic function, or hypertrophic diastolic dysfunction, or diastolic dysfunction of the pseudonormal pattern of the right ventricle [6]. The diagnosis of DD is very important since its presence in a patient with a cardiovascular disease is one of the criteria necessary for diagnosing chronic heart failure with a preserved ejection fraction [7].

Adequate work of the left heart chambers is impossible without adequate work of the right chambers: the amount of blood flowing into the left heart chambers depends on adequate work of the right chambers. Thus, a disorder in the right heart chambers makes a significant contribution to the development and progression of chronic heart failure. In this regard, it is necessary to diagnose diastolic function not only of the left ventricle, but also of the right one.

**The aim of the study**. The study is aimed at investigating the impairment of the diastolic function of the left and right ventricles in outpatients with arterial hypertension.

**Materials and methods**. The study included 361 outpatients, including 299 patients with arterial hypertension and 62 practically healthy people, who were examined in Klinika Uralskaya, LLC (Ekaterinburg, Russia) in the period from 2016 to 2019. The criterion for a patient to be included into the study was the presence of arterial hypertension with a preserved ejection fraction of both ventricles. The criteria for a patient to be excluded from the study were acute coronary syndrome, pulmonary embolism, congenital and acquired heart valve diseases and pulmonary diseases. All the patients underwent transthoracic echocardiography by a Philips HD-15 device (USA) with the use of the standard protocol with determining the diastolic function of both ventricles. To determine the diastolic function of the left and right ventricles, the velocities of a transmittal blood flow and a transtricuspid one in the early diastolic filling phase of both ventricles (peak velocity E, m/s), in the late atrial filling phase (peak velocity A, m/s), and their ratio (E/A) were determined echocardiographically. By tissue Doppler study, we determined the velocity of the fibrous rings of the mitral valve from the septal and lateral walls of the left ventricle and the tricuspid valve in the phase of filling of both ventricles in early diastole (e') and in the late phase of atrial filling (a'), their ratio (e'/a'), and the ratio of the velocity of the transmitral flow and the transtricuspid one in early diastole to the velocity of the lateral part and the medial part of the fibrous ring of the mitral valve (separately and averagely), and the lateral parts of the fibrous ring of the tricuspid valve, respectively (E/e'). The pattern of diastolic dysfunction in both ventricles was determined as follows: a relaxation impairment with E/A<0.8, e'<a', e'<8 (DD grade I, DD I), a pseudonormal pattern with 0.8<E/A<2, e'<a', e'<8 (DD grade II, DD II), and a restrictive pattern with E/A>2, e'< a', e'<8 (DD grade III, DD III) [8, 9]. The informed consent for research was obtained from all the patients. All patients gave the written consent for participation in the study, which was approved by the local ethic committee of the Institute of Medical Cell Technologies (Ekaterinburg, Russia).

In addition, 175 patients with arterial hypertension with a preserved left ventricular ejection fraction were evaluated for left ventricular diastolic function according to the recommendations of the American and European societies of echocardiographers for assessing left ventricular diastolic function (2016); according to these recommendations, three or four of the four ultrasound criteria (septal e'<7 cm/s and lateral e'<10 cm/s, average e/e' ratio >14, left atrial volume index (LAVI) > 34 ml/m2 and peak tricuspid regurgitation rate > 2.8 m/s) are necessary [10].

Statistical processing of the investigation results was performed according to the Student’s criterion in connection with the normal data distribution with the use of the Microsoft Excel spreadsheet program. Consistency with the normal distribution was checked by the visualization method and the Pearson test of fit. The differences were considered statistically significant at p<0.05. The data is presented as M±m, where M is the average value of the measured value, and m is the standard error.

**Results**

Depending on the grade, all the patients under study were divided into the following groups: LVDD I and RVDD I; LVDD I and RVDD II; LVDD II and RVDD II; LV normal diastolic function and RVDD II.

All the studied patients with arterial hypertension had diastolic dysfunction of the right ventricle of different patterns. The patients had a normal pulmonary artery systolic pressure (PASP), namely for LVDD I and RVDD I, PASP was 23.45±0.78 mmHg; for LVDD I and RVDD II, PASP was 20.91±0.69 mmHg; for LVDD II and RVDD II, PASP was 24.90±1.82 mmHg; for LV normal diastolic function and RVDD II, PASP was 21.56±0.78 mmHg, but it was higher than that of the control group (15.23±0.58 mmHg, p<0.05). The general characteristics of the patients are presented in Table 1.

Table 1. Clinical-demographic and echocardiographic characteristics of the patients with different patterns of DD of both ventricles

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | LVDD I and RVDD I (n=84) | LVDD I and RVDD II (n=77) | LVDD II and RVDD II (n=41) | | LV normal diastolic function and RVDD II  (n=97) | Control values  (n=62) |
| Gender (male) | 19 (18.8%) | 29 (37.6%) | 12 (29.2%) | | 36 (37.1%) | 26 (39.3%) |
| Age (years) | 69.61±0.77\* | 69.04±3.43\* | 65.40±1.66\* | | 50.08±1.08\* | 35.13±1.30 |
| Coronary artery disease | 9 (10.7%) | 8 (10.3%) | 1 (2.4%) | | - | - |
| Atrial fibrillation | 7 (8.3%) | 7 (9%) | 4 (9.7%) | | - | - |
| Diabetes mellitus | 3 (3.6%) | 1 (1.3%) | ~~-~~ | | ~~-~~ | ~~-~~ |
| Arterial hypertension duration (years) | 19.14±1.42 | 19.29±1.35 | 18.27±1.36 | | 3.92±0.48 | ~~-~~ |
| Left atrium in the left lateral position (mm) | 39.75±0.68\* | 37.52±0.68\* | 37.80±0.88\* | | 34.57±0.59\* | 31.53±0.50 |
| LA volume (ml) | 87.04±1.95\* | 76.36±2.48\* | 83.89±4.38\* | | 63.81±1.50\* | 49.29±1.97 |
| LAVI | 47.19±1.10\* | 41.37±0.80\* | 41.29±1.36\* | | 35.65±0.62\* | 30.44±0.98 |
| Simpson's ejection fraction (%) | 66.92±0.77\* | 67.47±0.91\* | 68.51±1.10\* | | 65.65±0.99 | 62.89±1.40 |
| LV EDV (ml) | 119.72±4.25\* | 122.50±5.74\* | 130.78±8.88\* | | 143.15±5.38\* | 106.27±4.18 |
| LV ESV (ml) | 39.97±2.15 | 39.25±2.96 | 42.56±4.15 | | 50.04±3.09\* | 40.74±2.27 |
| Stroke volume (ml) | 80.43±2.58\* | 82.72±3.42\* | 88.40±5.50\* | | 94.52±3.17\* | 73.67±2.06 |
| Transmitral E/A | 0.71±0.01\* | 0.75±0.02\* | 1.23±0.04\* | 1.23±0.03\* | | 1.61±0.04 |
| Average Е/e' | 11.08±0.38\* | 8.90±0.28\* | 11.93±0.88\* | 7.70±0.23\* | | 6.83±0.28 |
| Septal е'/а' | 0.62±0.01\* | 0.63±0.01\* | 0.74±0.04\* | 1.03±0.08\* | | 1.53±0.04 |
| LV lateral е'/а' | 0.65±0.02\* | 0.66±0.02\* | 0.79±0.06\* | 1.43±0.03\* | | 1.91±0.07 |
| PASP (mm Hg) | 23.45±0.78\* | 20.91±0.69\* | 24.90±1.82\* | 21.56±0.78\* | | 15.23±0.58 |
| Transtricuspid E/A | 0.77±0.01\* | 1.31±0.03\* | 1.36±0.04\* | 1.38±0.02\* | | 1.58±0.03 |
| RV lateral е'/а' | 0.71±0.07\* | 0.59±0.02\* | 0.67±0.01\* | 0.71±0.02\* | | 1.57±0.06 |
| Right atrium (area, cm2) | 18.31±0.33\* | 17.44±0.49\* | 16.94±0.46\* | 16.34±0.27\* | | 14.49±0.56 |
| IVC | 16.59±0.37 | 16.52±0.32\* | 17.09±0.47 | 17.52±0.27 | | 17.60±0.43 |

Note: LAVI is the left atrial indexed volume; EDV is the end-diastolic volume; ESV is the end-systolic volume; E/A is the ratio of the blood flow velocity in the phase of early diastolic ventricular filling to the filling velocity in the late atrial filling phase; Е/е' is the ratio of the early-diastolic blood flow velocity to the velocity of the lateral part and the medial part of the fibrous ring of the mitral valve (separately and averagely), and the lateral part of the fibrous ring of the tricuspid valve, respectively; е'/а' is the ratio of the movement velocities of fibrous rings of the mitral valve from the septal and lateral walls of the left ventricle and the tricuspid valve in the phase of filling of both ventricles in early diastole (e') to the late atrial filling phase (а'); IVC is the inferior vena cava; \* indicates the significance of the differences between each group of patients and the control group, p<0.05.

84 patients showed signs of diastolic dysfunction of the left and right ventricles of grade I (LV: E/A=0.71±0.01, septal e/a'=0.62±0.01 m/s, lateral e/a'=0.62±0.01 m/s; RV: E/A=0.77±0.01, lateral e/a'=0.71±0.07 m/s). 77 patients showed signs of diastolic dysfunction of the left ventricle of grade I and the right ventricle of grade II (LV: E/A=0.75±0.02, septal e/a'=0.63±0.01 m/s, lateral e/a'=0.66±0.02 m/s; RV: E/A=1.31±0.03, lateral e/a'=0.59±0.02 m/s). 41 patients showed signs of diastolic dysfunction of the left and right ventricles of grade II (LV: E/A=1.23±0.04, septal e/a'=0.74±0.04 m/s, lateral e/a'=0.79±0.06 m/s; RV: E/A=1.36±0.04, lateral e/a'=0.67±0.01 m/s). In 97 patients, diastolic dysfunction of the right ventricle of grade II was detected, while the diastolic function of the left ventricle was not impaired (LV: E/A=1.23±0.03, septal e/a'=1.03±0.08 m/s, lateral e/a'=1.43±0.03 m/s; RV: E/A=1.38±0.02, lateral e/a'=0.71±0.02 m/s). This group had a short duration of arterial hypertension (3.92±0.48 years) versus the other groups (LVDD I and RVDD I, LVDD I and RVDD II, LVDD II and RVDD II) having 19.14±1.42, 19.29±1.35, and 18.27±1.36 years of hypertension, respectively (table 1).

Out of 175 studied patients having hypertension with preserved ejection fraction of the left ventricle, all the patients had a pattern of diastolic dysfunction: the diastolic pattern of left ventricular dysfunction of grade I was detected in 145 cases (E/A=0.73±0.01; septal e'/a'=0.62±0.01; lateral e'/a'=0.65±0.02); the pattern of diastolic dysfunction of grade II was detected in 30 cases (E/A=1.24±0.04; septal e'/a'=0.74±0.05; lateral e'/a'=0.80±0.07) as compared to control values (E/A=1.61±0.04; septal e'/a'=1.53±0.04; lateral e'/a'=1.91±0.07). Among these 175 patients, according to the recommendations of the European and American societies of echocardiographers for the diagnosis of diastolic dysfunction (2016), diastolic dysfunction [10] was diagnosed only in 32 patients (18.3% of cases), taking into account the presence of three or four criteria out of four (Table 2): E/e'=16.56±1.05; septal e'=5.01±0.21; lateral e'=7.15±0.32; LAVI=48.31±0.78; PASP=30.96±2.05. In 71 patients (40.6% of cases), there were two criteria out of four (E/e'=9.97±0.29; septal e'=6.14±0.161; lateral e'=8.15±0.21; LAVI=43.91±0.90; PASP=22.38±0.75), indicating indeterminate diastolic dysfunction. The remaining 72 patients (41.1%) had one or no criteria (E/e'=8.24±0.26; septal e'=7.76±0.24; lateral e'=10.41±0.26; LAVI=37.83±1.14; PA systolic pressure =20.26±0.87), i.e. they had a normal diastolic function.

Table 2. The diagnosis of left ventricular diastolic dysfunction in the patients with a preserved ejection fraction according to the recommendations of the European and American societies of echocardiographers for the diagnosis of diastolic dysfunction (2016)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Diastolic dysfunction (n=32) | Indeterminate  (n=71) | Normal diastolic function (n=72) | Control values |
| Average E/e' | 16.56±1.05\* | 9.97±0.29\* | 8.24±0.26\* | 6.83±0.28 |
| Septal e' (cm/s) | 5.01±0.21\* | 6.14±0.16\* | 7.76±0.24\* | 13.08±0.35 |
| Lateral e' (cm/s) | 7.15±0.32\* | 8.15±0.21\* | 10.41±0.26\* | 17.55±0.51 |
| LAVI, (ml/m2) | 48.31±0.78\* | 43.91±0.90\* | 37.83±1.14\* | 30.44±0,98 |
| PASP | 30.96±2.05\* | 22.38±0.75\* | 20.26±0.87\* | 15.23±0.58 |

Note: LAVI is the left atrial indexed volume, PASP is the pulmonary artery systolic pressure, \* indicates the significance of the differences in the groups of patients and control subjects, р <0.05.

**Discussion**

Diagnosing the diastolic function of both ventricles in outpatients having arterial hypertension showed the presence of patterns of diastolic dysfunction of the heart ventricles in all the studied patients: out of 202 patients, 84 had a pattern of diastolic dysfunction of the left and right ventricles (grade I), 77 patients had a pattern of diastolic dysfunction of the left ventricle (grade I) and of the right ventricle (grade II), 41 patients had a pattern of diastolic dysfunction of both heart ventricles (grade II). Three of the patients with hypertension and coronary heart disease had impaired left ventricular relaxation with normal diastolic function of the right ventricle; they were excluded from the statistical analysis in order to maintain uniformity. It should be noted that these patients had increased right ventricular systolic function.

Thus, in outpatients with arterial hypertension and chronic heart failure, an impairment of the relaxation of both ventricles was detected. It is generally accepted that, in patients with arterial hypertension, heart failure begins with the left heart chambers, namely remodeling and diastolic dysfunction of the left ventricle. This is one of the reasons that in everyday clinical practice more attention is paid to the impairment of the diastolic function of the left ventricle as compared to the right one.

It should be noted that the diastolic dysfunction of the right ventricle in the studied patients was also observed at normal systolic pressure in the pulmonary artery; this is confirmed by a number of studies [2, 3]. In this case, the development of relaxation disorders of the right ventricle is not due to its work against increased pressure in the pulmonary artery, but, probably, due to the activation of the sympathoadrenal and renin-angiotensin-aldosterone systems and the effect of hormones circulating in blood on the receptors of the tissue of the right chambers of the heart.

For the first time, this study has revealed an impairment of the diastolic function of the right ventricle with preserved diastolic function of the left ventricle in patients with arterial hypertension; this can be used in practice as an early ultrasound sign of the development of heart failure. Normally, the main function of the heart is blood supply to organs and tissues adequate to their functions and the level of plastic processes in them; therefore, a changed plastic exchange of organs and tissues is likely to lead to elevated blood pressure and increased blood flow to them by activating the neurohormonal system. The increased blood flow to the organs depends on the left ventricle capacity; in turn, the diastolic volume of the left ventricle depends on the volume of the blood that comes from the right ventricle. In most cases, the blood flow to the heart is the decisive factor determining the value of the end-diastolic volume of the ventricles [11]. Probably, in this connection, the relaxation of the right ventricle is the first to be impaired.

Myocardial relaxation is an energy-dependent process in contrast to the systole of the heart; therefore, the detection of diastolic dysfunction indicates an energy metabolism disturbance in the myocardium. Thus, the impairment of relaxation develops at the first signs of energy deficiency, long before the impairment of contraction. Thereby, we see that the earlier diastolic dysfunction is diagnosed, the more effective the therapy will be.

Diagnosing the diastolic function of the ventricles is one of the most important components of the echocardiographic protocol, but it is not easy to diagnose [12]. In this study, 175 outpatients with arterial hypertension had left ventricular diastolic dysfunction according to the criteria of the European and American societies of echocardiographers in only 18.3% of the patients; in 40.6% of cases, diastolic dysfunction remained indeterminate (that is, it requires further examination); in 41.1% of cases, diastolic function was assumed to be normal.

Thus, the diagnostics of diastolic ventricular function is a very important and ambiguous task. The presence of left ventricular diastolic dysfunction is one of the criteria for making a diagnosis of CHF with a preserved ejection fraction [7], whereas the echocardiographic estimation of its presence made according to various criteria can both increase and significantly reduce the number of patients with CHF, and this will have a direct effect on the tactics of patient management.

**Conclusion**. In patients having chronic heart failure with arterial hypertension, diastolic dysfunction of the right ventricle accompanies diastolic dysfunction of the left ventricle, regardless of the presence or absence of pulmonary arterial hypertension. Diastolic dysfunction of the right ventricle with normal diastolic function of the left ventricle is an earlier disorder in patients with a short period of arterial hypertension; this can be used in practice as an early ultrasound sign of heart failure development.

**Conflict of interests**

We confirm that there is no financial support or conflict of interests to be reported.

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