https://doi.org/10.38109/2225-1685-2018-2-4-15

ISSN 2225-1685 (Print)
ISSN 2305-0748 (Online)

Sohibnazarova V. Kh., Saidova M.A., Tereshchenko S.N., Belevskaya A.A.

EVALUATION OF DEFORMATION OF THE LEFT VENTRICLE AND LEFT ATRIUM, AND THE ROTATIONAL PROPERTIES OF THE LEFT VENTRICLE IN PATIENTS WITH CHF ACCORDING TO THE ECHOCARDIOGRAPHIC TECHNOLOGY OF NON-DOPPLER IMAGING IN TWO AND THREE-DIMENSIONAL REGIMENS

Federal State Budgetary Institution «National Medical Research Center of Cardiology» of the Ministry of Health of Russia, Moscow, Russia

SUMMARY

Objective. To study the peculiarities of deformation, rotation properties, twisting and untwisting of the left ventricular(LV) , evaluation of the function of left atrium in patients with CHF with preserved and reduced ejection fraction of the left ventricular according to Echocardiography technology Non Doppler imaging in two and three-dimensional regimes (2D and 3D Speckle tracking imaging).

Material and methods. The study included 70 patients with chronic heart failure (CHF) with preserved (Group I) and reduced (Group II) ejection fraction (EF) of the left ventricular (LV). In addition to the standard Transthoracic echocardiography, all patients were assessed the deformation of the left ventricle (LV) and left atrium (LA) as well as the rotational properties of the LV using the technology of myocardial image in two and three-dimensional regimen.

Results. Studies show that patients CHF deformation of the left ventricular (LV) and left atrium (LA), and the rotational properties, twisting and unwinding of the (LV) according to the two methods were lower than the control group (CG). In both groups there was a reliable increase the size and volume of LA, as well as a decrease the deformation of the LA in it phases and global longitudinal deformation. The values of the global longitudinal deformation of the LA in patients group I and II (-6,68±3.0% and-6,63±3.3%, respectively) were reliably lower compared to CG (-9.3±7.3%) ($p < 0.001$). A good correlation was found between LV deformation and LV EF in patients group I ($r = -0.39$) ($p < 0.001$) and in group II ($r = 0.35$)($p < 0.001$).

Conclusions. When estimating the deformation of the left ventricular according to the data of two technologies, the three-dimensional mode demonstrated lower myocardial deformation in comparison with the three dimensional regime, which may be associated with a fuller assessment of the deformation of the left ventricular myocardium. Also increased global longitudinal deformation of LA can be an early predictor of diagnostics of CHF.

Keywords: *Chronic heart failure, left ventricular ejection fraction, deformation, rotation properties, twisting, untwisting*

Information about authors:

Saidova Marina Abdulatipovna	The Head of the Ultrasound of Methods of Diagnostic of the National Medical Research Center of Cardiology. Professor, Doctor of Medical Sciences, tel. 8 (495) 414-63-57, 121552, Russia, Moscow, st. 3rd Cherepkovsky, 15 a
Tereshchenko Sergey Nikolaevich	The Head of Department of myocardial diseases and heart failure of the National Medical Research Center of Cardiology. Professor, Doctor of Medical Sciences, tel. 8 (495) 414-61-17, 121552, Russia, Moscow, st. 3rd Cherepkovsky, 15 a
Belevskaya Anna Andreevna	Research assistant of the Ultrasound of Methods of Diagnostic of the National Medical Research Center of Cardiology, 121552, Russia, Moscow, st. 3rd Cherepkovsky, 15 a
Responsible for correspondence: Sohibnazarova Vasila Khudjanazarovna	Postgraduate student of the Ultrasound of Methods of Diagnostic of the National Medical Research Center of Cardiology, email: sohibnazarova.vasila@gmail.com, tel. 8-925-335-34-39, 121552, Russia, Moscow, st. 3rd Cherepkovsky, 15 a

✉ **sohibnazarova.vasila@gmail.com**

For citation: Sohibnazarova V.Kh., Saidova M.A., Tereshchenko S.N., Belevskaya A.A. Evaluation of deformation of the left ventricle and left atrium, and the rotational properties of the left ventricle in patients with CHF according to the echocardiographic technology of Non-Doppler imaging in two and three-dimensional regimens. Eurasian heart journal. 2018, May 25; 2:10-15

INTRODUCTION

Traditionally, chronic heart failure (CHF) is associated with the deterioration of the contractile ability of the myocardium, which is reflected in the reduction of the ejection fraction (EF) of the left ventricle (LV). However, a significant part of the patients suffer CHF with the preserved ejection fraction (EF) of the left ventricular (LV) (>45%), and the proportion of such patients by different estimates reaches 30-50% [1]. Therefore, for the diagnosis of CHF with the preserved EF of the LV it is necessary to have even four criteria: 1) Symptoms, typical of CHF; 2) Physical characteristics typical of CHF; 3) Normal or slightly reduced EF of the LV in the absence of dilatation of the LV; 4) Appropriate structural changes of the heart, such as ventricular hypertrophy (LVH), dilatation of the left atrium LA and/or LV diastolic dysfunction [2].

Visualizing methods of research, in particular echocardiography (Echo) play a central role in the diagnosis of CHF. However, even with the use of different parameters echo there are restrictions for diagnosis of CHF with preserved EF. As a result, many researchers have recently used new technologies such as Speckle Tracking Imaging in two and three-dimensional modes. The technology of estimation of myocardial deformation (strain) allows calculating parameters which are important for correct estimation of systolic and diastolic function of LV. Unlike the Tissue Doppler imaging (TDI) this technology is devoid of restrictions related to the direction of movement of the object and ultrasonic beam. The method allows to conduct more complex analysis and provides high accuracy of measurements for quantitative estimation of global and regional function of LV. It also provides an opportunity to receive information about the direction and speed of the myocardial movement throughout the entire heart cycle. Thus, with the help of Non- Doppler technology, it became possible to investigate deformation, apical and basal twisting and untwisting of the heart during the systole and diastole, as well as to evaluate mechanical function of the LA. It should be noted that the LA performs not only the reservoir function during the systole of the ventricles and the conduction function in the period of diastole, but also active contractile function in the period of late diastole. The importance of the structural-functional parameters of the LA for prediction of adverse clinical outcomes in patients with CHF with the preserved LV EF is virtually undefined.

The purpose of this work is to study the peculiarities of deformation, rotation properties, twisting and untwisting of the left ventricular, evaluation of the function of left atrium in patients CHF with the preserved and reduced ejection fraction according to Echocardiography technology non- Doppler myocardial images in two-dimensional and three-dimensional modes (2D and 3D Speckle Tracking Imaging).

MATERIAL AND METHODS OF RESEARCH

The study included 70 patients (29 women and 41 men) aged 70,0±17,9 years, hospitalized in the Department of Myocardial diseases and heart failure of FSBI «National Medical Research Center of Cardiology» of the Ministry of Health of Russia . Patients were included in the study with CHF classes I-IV (NYHA), as a result of coronary heart disease, dilated cardiomyopathy or arterial hypertension (AH). All patients had sinus rhythm. Patients with CHF were divided into 2 groups: I Group-CHF with the preserved ejection fraction (≥45%), II Group-CHF with the reduced ejection fraction (<45%). Criteria of exclusion from the study: non compaction cardiomyopathy, congenital and acquired heart defects, acute myocardial infarction and LBBB. The control group (CG) comprised 20 healthy volunteers (12 women and 8 males) aged 26.5±2.8 years.

Transthoracic Echo was performed on an ultrasonic device of the Expert class Vivid E9 (GE Healthcare, USA) with the use of sensor M5S-D for registration of images in 2D mode and matrix sensor 4V-D for registration of images in 3D mode. A synchronous recording of Electrocardiogram was performed during the study to determine the phases of the heart cycle. The study was conducted using standard echocardiographic accesses and modes. In order to study the deformation, rotation, twisting and untwisting of the LV was performed Echo in two-dimensional mode according to the standard method. In the subsequent images were processed using the Non- Doppler image technology using the EchoPAC PC program (GE Healthcare, USA).

The estimation of sizes and volumes of LA and LV, thickness of LV walls, mass and mass index of the LV according to Echo data was carried out according to recommendations on quantitative estimation of structure and function of cardiac chambers [3]. The global systolic function of the LV was estimated from apical access in 4-and 2-chamber positions with the calculation of the LV EF by the Simpson method. To assess the diastolic function of the LV calculated the parameters of the transmitral flow according to the Pulse-wave Doppler (speed of early diastolic filling (E), the rate of late diastolic filling (A), their ratio (E/A)) and indicators of the movement of lateral and septal sections of the mitral valve fibrous ring according to TDI (EmL, AmL, Ems, AMS, E/Em).

All participants of the research, conducted analysis of Global longitudinal (GLS), radial (GRS) and circumferential (GCS) strain. For this purpose the recording of digital projector from apical access in 4-, 2-and 3-chamber positions was performed. To obtain the optimal result, images were registered with a frame rate of 70 – 100 per second. The system automatically generated the contour, indicating the segments that are not suitable for analysis. The analysis calculated the maximum values of myocardial strain for each of the 17 LV segments, the average strain values for each of the 3 positions and the average deformation value for the entire LV.

Within the framework of the study, we studied the parameters characterizing the geometry (volume), the function (change in volume), and the mechanics (longitudinal strain) of the LA. A vector analysis of the longitudinal strain was also performed during the four phases of the left atrium LA [4].

To calculate the global longitudinal, radial, circumferential strain and global area strain (GAS) in 3D mode (4D Strain), images were recorded with a frame rate of 25-50 per second using the Multi-Slice option from the apical 4-chamber position during four or six heart cycles. Then the image of the LV was post processed using the option of automatic quantitative analysis (4D AutoLVQ), which allowed to obtain strain values for each segment and global deformation of the LV in longitudinal, radial and circumferential directions, as well as the global area strain [5].

STATISTICAL DATA PROCESSING

Static data processing was carried out using the program package Statistica, version 6. Average values are represented as average±standard deviation (M±SD) or as median and interquartile scale (25th and 75th percentile). In comparison of three groups for quantitative variables the criteria of Kruskala-Wallis, for qualitative-Pearson criterion was applied.

RESEARCH RESULTS AND DISCUSSION

In the evaluation of the systolic and diastolic functions of the LV in patients with reduced EF (II Group), the reliable differences in comparison with patients with the preserved EF (I Group) and control group (CG) (p<0.001) (table 1) are revealed. In the CG, the values of all Echo parameters corresponded to the normal, which confirms the absence of heart diseases in healthy category of persons.

Comparing the parameters of the systolic function of LV in patients of the II group there was a reliable decrease of EF (33,0±9.8%) compared to the patients I group (61,9±5.4%) and CG (62,8±3.4%) (p<0.001). At a pair comparison of echocardiographic indicators in patients CHF with the preserved and reduced EF were revealed statistically significant differences on a number of parameters of the diastolic function (E, Em (s), Em (l) (see table). In patients with CHF with preserved EF there is an increase the mass (LVM) and mass index of the LV (LVMI), which testifies to the LV remodeling. In patients with CHF with reduced EF there was also an increase in mass and mass index of LV due to the increase of LVEDD. It is noted that in patients CHF values of E/E ' were higher than in CG (p < 0.001), which indirectly confirms the dysfunction of the LV diastolic function and allows to use these indicators as additional markers of heart failure.

According to 2D Speckle tracking in patients of the II group, there was a reliable decrease GLS (-8.4±3.3%) in comparison with CG (-17.8±7.3%), however, in patients of the I group the obtained values were below the reference range (-15.0±3.0) (P<0.05). The GRS indices were lower in patients of the II group (12.7±7.3%) compared to I group (32,0±13,0%) and CG (43,0±4.2%) (p<0.05). In case of GCS in patients I group (-18,0±4.8%) there were no reliable differences compared to control group CG (-18.6±3.2%), however, it was much lower in patients of II group (-7.5±3.8%) (P<0.05)

Previous studies showed that the decrease of GLS was noted in the early stages of remodeling due to hypertension (concentric remodeling and concentric hypertrophy) [6.7]. Reduction of GLS occurs also in patients with arterial hypertension (AH) with normal EF in the absence of the heart failure.

In another work Van H., et al., pointed that in patients CHF with preserved EF initially decreased LV circumferential and longitudinal strain in comparison with healthy persons [8]. According to Cioffi G., decreasing of the circumferential and/or longitudinal strain is observed in almost a quarter of patients CHF with the preserved EF, while the radial deformation remains unchanged [9]. This may be due to the presence of left ventricular hypertrophy in patients with arterial hypertension (AH) or CHF with the preserved EF. The lack of coherence in the work on CHF with preserved EF can be explained by the inclusion of patients of varying degrees of severity in different studies. So, Petersen Ch. V., et al., believes that the values of longitudinal, radial and circumferential strain correlate with the tolerance to the physical load [10].

Table 1. Indicators of systolic and diastolic function of the LV in patients CHF and control group according to the 2D Echo

Parameters \ Group	I group n=30	II group n=40	CG n=20
EDV, ml	82,8±34,4	204,5±84,0*	96,4±18,4
ESV, ml	32,3±20,4	143,3±73,1*	28,2±6,6
EF, %	61,9±5,4%^	33,0±9,8%*	62,8±3,4%
LVM, gr	234±35,2 *^	236,0±34,6*	163,9±12,1
LVMI gr/m²	121,0±12,1 *^	122,6±15,6*	81,7±16,0
IVS, cm	1,2±0,1*^	1,0±0,1	1,0 ±0,1
PWD, cm	1,1±0,1	1,1±0,1	0,9±1,1
E	90,1±23,2*^	80±20,6*	72,2±4,9
E/A	1,35±0,5^	1,65±0,9*	1,4±1,0
Em(s)	5,57±1,0*	5,37±1,8*	10,8±1,9
Em(l)	5,5±1,3*	5,8±1,1*	10,8±1,8
E/E′	16,0±4,2*^	17,2±15,9*	6,5±1,1

*Note * p <0.001 compared with the control group,*
^ p <0.001 compared with the II group.

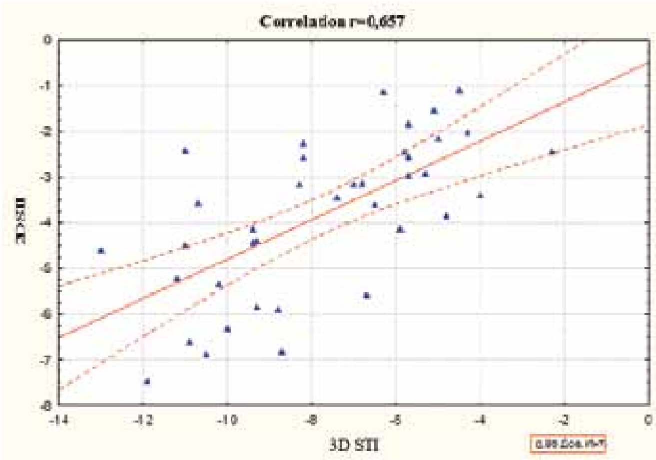

Figure 1. Correlation analysis of global longitudinal deformation in 2D and 4D Strain in patients of the II group

The PARAMOUNT study (Prospective Comparison of ARNI with ARB on Management of Heart Failure With Preserved Ejection Fraction Trial) included patients with heart failure II-IV classes (NYHA), LV EF, 45% and level NT-ProBNP >400 pg/ml, which took valsartan for 12 weeks. After a multicenter clinical study, the authors came to the following conclusions: In patients with CHF with the preserved EF value of longitudinal and circumferential strain were lower compared to CG and patients with AH; The longitudinal and circumferential strain figures were significantly lower even in patients with LV EF >55% in the absence of coronary heart disease in history. Both longitudinal and circumferential strain had no correlation with the indicators of diastolic dysfunction like Em and E/Em. A strong correlation of longitudinal strain with the level of NT-ProBNP was revealed, which is the main index of the diagnosis of the progression of heart failure [11].

Parameters of rotational properties, twisting and untwisting of the LV in patients of II group were much lower in comparison with CG, but in patients of I group did not differ significantly from CG. Along with this, we found that the patients CHF both groups had a reliable decrease in the rotation parameters of the LV, both at the level of basal, and apical segments in systole and in the period of early diastole (r = 0.01) (p < 0.01). The results of this study are consistent with the data of Park S. Ch. et al., in their work carried out an evaluation of the rotation and twisting of the LV in patients CHF with a preserved EF and compared the data with healthy category people [12]. In patients with the diastolic dysfunction 1 degree rotation and twisting of the LV were much higher than in control CG. However, as the diastolic dysfunction progressed (2 and 3 degrees), there was a significant decrease in these parameters. The authors believe that high rotation values at the early stage of the diastolic dysfunction can be a predictor of subendocardial dysfunction of the LV. It is possible to assume that in patients with CHF with preserved EF increasing of the values of rotation and twisting of LV is the initial stage of diastolic dysfunction.

In patients of both groups there was a decrease in global endocardial and epicardial strain in comparison with CG (p = 0.01), which may indicate an early damage of these layers in patients CHF.

As it follows from the table № 2, patients I groups had a negative correlation between the untwisting of the LV and EF, in patients II group-a negative correlation between GLS and GCS, global deformation epicardial and endocardial layers and ejection fraction and positive correlation between the GRS and EF.

In our study the analysis of deformation properties was carried out according to the data of 3D Speckle Tracking technology with the definition of the following parameters: global longitudinal strain, global circumferential strain, global radial strain, global area strain (GAS) and global peak deformation (global peak longitudinal strain, GPSL). In patients I group, the values of LVM and LVMI according to 3D Echo both in systole and in diastole were higher than in the II group and CG (p<0.01), which testifies to the concentric LV hypertrophy (table 3).

By analogy with the results obtained with the use of the 2D mode, in patients with CHF with preserved EF according to the data of 3D Speckle Tracking there was a decrease in the GLS and GRS (table 4). However, in comparison with the two- dimensional mode in the use of three-dimensional mode in patients I group also noted a decrease in the circumferential deformation (P<0.01). In patients of CHF I and II group the decrease of global area strain and the global peak longitudinal strain was revealed as compared to (CG) (p<0.01).

In patients I group global area strain was-16.3±3.0%, which may indicate a decrease in global contractility of the myocardium, despite the preserved EF, as this parameter reflects the total distortion of the left ventricular myocardium in the Real-time mode. In patients of the II group there was a reliable decrease the values of GAS (-4.2±8.2%) compared to I group and CG (-17.1±3.7%) (p<0.001).

In the literature there is contradictory information about the change of the LV strain parameters using three-dimensional mode in patients with CHF with preserved EF. According to some authors, at the value of GAS ≤ 15% in patients CHF with preserved and reduced EF is noted higher morbidity and mortality [13].

The next task of our research was to compare 2D and 3D Speckle Tracking Imaging. The results of the analysis show that the indicators obtained in three-dimensional mode, in patients CHF were lower in comparison with the two-dimensional regimen, but in CG did not go beyond the reference values.

According to the correlation analysis of the patients of the I group, there was a good correlation between global longitudinal, radial

Table 2. Correlations of a non-Doppler image of the myocardium in two-dimensional mode with FC of CHF and LV EF

Parameters	I group (n=30)				II group (n=40)			
	CHF		EF		CHF		EF	
	r	p	r	p	r	p	r	p
GLS, %	0,21	>0,05	0,12	>0,05	0,22	>0,05	**-0,57**	**<0,05**
GCS, %	0,33	>0,05	0,32	>0,05	0,14	>0,05	**-0,45**	**<0,05**
GRS, %	0,12	>0,05	0,15	>0,05	**-0,31**	**<0,05**	**0,31**	**<0,05**
Torsion Rate, °/c	0,15	>0,05	**-0,37**	**<0,01**	0,18	>0,05	0,21	>0,05
Global epicardial strain, %	0,22	>0,05	0,32	>0,05	**-0,35**	**<0,05**	**-0,54**	**<0,05**
Global endocardial strain, %	0,21	>0,05	0,23	>0,05	**-0,31**	**<0,05**	**-0,53**	**<0,05**

Correlation analysis Spearman rank R

Table 3. Indicators of LVM and LVMI according to 3D Echo in patients with CHF and CG

Group / Parameters	I group n=30	II group n=40	CG n=20	p for the trend*
LVM (syst.), gr	123,0* [108,0;128,0]	124,0* [110,0;132,0]	105,9 [94,6; 20,0]	**<0,001**
LVMI, gr/m²	74,3* [66,0;76,0]	68,5* [52,0;72,0]	70,5 [64,0; 77,0]	**<0,001**
LVM (diast.), gr	123,4* [100,0;128,0]	124,6* [113,3;130,0]	109,9 [100,0;120,0]	**0,04**
LVMI, gr/m²	66,7 [57,0;75,0]	67,9 [54,5;75,0]	64,8 [56,0; 75,0]	**1,00**

*Note * p<0.001 in compare to the control group*

Table 4. Deformation properties of left ventricular according to the technology 3D Speckle Tracking in patients CHF and CG

Group / Parameters	I group n=30	II group n=40	CG n=20	p for the trend*
GLS, %	-7,3 [-10,0;-6,0] *^	-3,5 [-4,0;-2,0]*	-12,6 [-15,2;-10,5]	**<0,001**
GCS, %	-10,3 [-13,0;-9,0] *^	-4,6 [-6,0;-3,0]*	-17,9 [-19,5; -13,0]	**<0,001**
GRS, %	21,8 [16,0;26,0] *^	8,8 [5,0;12,0]*	25,5 [20,5; 32,0]	**<0,001**
GAS, %	-16,3 [-20,0;-12,0] *^	-7,9 [-10,0;-5,0]*	-21,1 [-26,5; -19,5]	**<0,001**

*Note * p < 0.001 compared to the control group, ^ p < 0.001 compared to the II group*

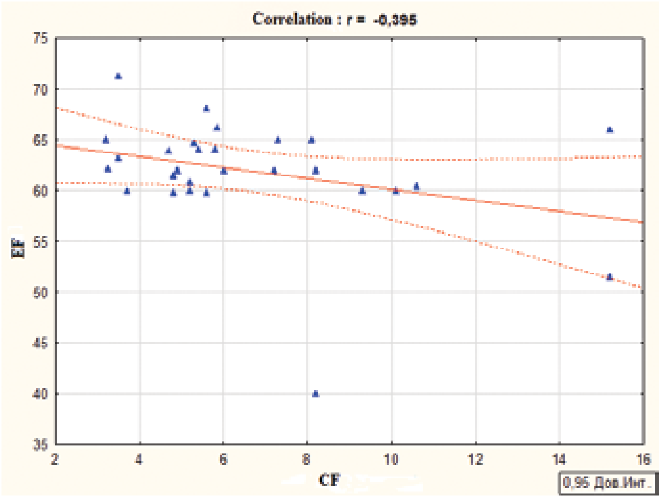

Figure 2. Correlation analysis of conduit function (CF) of the left atrium and EF in patients of I group

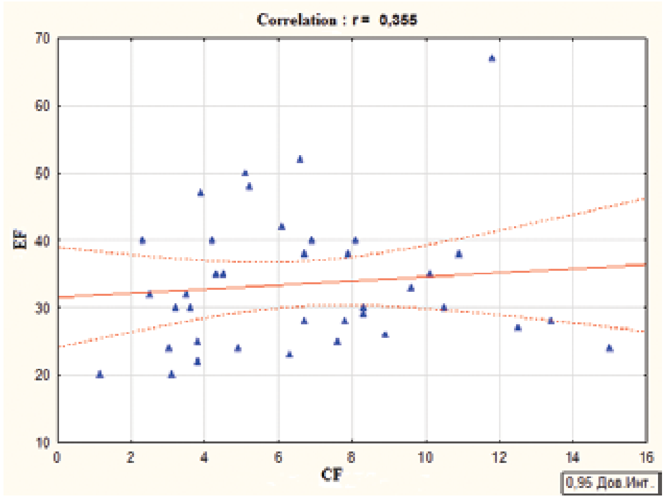

Figure 3. Correlation analysis of conduit function (CF) of left atrium and EF in patients of II group

and circumferential strain according to 2D Speckle Tracking with the global area strain according to 3D Speckle Tracking Imaging. There is a strong correlation between the global area strain and the layers of global endocardial and epicardial strain in patients of both groups, which may indicate subendocardial damage of the left ventricular myocardium. As it follows from table 5, the patients of both groups found a reliable connection between the global area strain and 2D Speckle Tracking, but in the second group the values were much higher.

Another task of our research was the analysis of the mechanical function of the LA in patients with CHF with a preserved and reduced EF. It was revealed that patients CHF both groups had a reliable decrease in reservoir and conduit functions of the LA. In patients of the II group the values of these parameters were reliably lower in relation to the I group CG. It should be emphasized that the patients of the first group noted a decrease in the reservoir function (16.7±6.8%), which is a clinically significant para meter in patients CHF. With regard to the contractile function of the LA, there was no credible difference between the two groups and compared to CG. The values of the global longitudinal deformation of the LA in patients I and II group (-6,68±3.0% and-6,63±3.3%, respectively) were reliably lower compared to CG (-9.3±7.3%) (p<0.001).

We detected a negative correlation between the conduit function of LA and EF in patients of I group (r = -0.39, p<0.001) and a positive correlation in patients of II group (r = 0.35, p<0.001), which may testify to worsening of the prognosis in patients with CHF with a reduced EF (Fig. 2, 3).

According to Aung S. et al., in the analysis of the deformation of LA and evaluation of its role in the diagnosis of CHF in patients with the preserved EF a strong negative correlation between the reservoir phase of the LA and BNP and moderate negative correlation with the index of the LA volume [14]. The authors noted that the reduction of the reservoir function of the LA of < 17.5% can be an early predictor of the diagnosis of CHF with the preserved EF.

CONCLUSION

The results obtained in the present study shows that the use of modern echocardiographic technologies in patients with CHF

Table 5. Correlation analysis of the global area of left ventricular deformation and 2D Speckle Tracking indicators in patients CHF

Parameters	GAS I group n=30		GAS II group n=40	
	r	p	r	p
GRS, %	**-0,39**	**<0,05**	**-0,42**	**<0,05**
GCS , %	**0,48**	**<0,05**	0,23	>0,05
GLS, %	**0,46**	**<0,05**	**0,72**	**<0,05**
Global epicardial strain, %	**0,39**	**<0,05**	**0,76**	**<0,05**
Global endocardial strain, %	**0,40**	**<0,05**	**0,75**	**<0,05**

(Correlation analysis Spearman rank R

Table 6. Evaluation of the functions of the left atrium in patients CHF and CG.

Group / Phases of LA, %	I group n=30	II group n=40	CG n=20	p for the trend*
Reservoir	16,7±6,8*^	12,8±6,1*	29,3±5,1	**<0,001**
Conduit	8,13±4,1*^	6,19±4,5*	14,1±8,8	**<0,001**
Contractile	-0,32±0,8*^	-0,58± 0,7*	-1,30±2,2	**<0,001**
GLS	-6,68±3,0*	-6,63±3,3*	-9,3±7,3	**<0,001**

*Note * p <0.001 compared with the control group, ^ p <0.001 compared with the group II* with preserved and reduced EF allows more accurate estimation of the left ventricular strain. As part of this study it is shown that in patients with CHF both with preserved and with the reduced EF is noted the decrease of functions of left atrium as well as the parameter of global longitudinal strain. The decrease of the reservoir function of the left atrium reflects the increase in the pressure of left ventricular filling, which is mainly observed in patients with CHF, but also can be compensatory mechanism of impairment of left ventricular filling.

Conflict of Interest Declaration: Authors declare no conflict of interest.

REFERENCES

1. *Mareev V. U., Danielyan M. O, Belenkov U.N. On behalf of the working group of the study EPOHA-O-HSN. Comparative characteristics of patients with CHF, depending on the value of EF according to the results of the Russian multicenter study EPOHA-O-HSN. Serdechnaya Nedostatochnost. 2006; 7: 164-171 [in Russian].*
2. *Tereshchenko S. N, Narusov O. U, Zhirov I. V. European recommendations for the treatment and diagnosis of acute and chronic heart failure in 2016. What's new? Serdechnaya Nedostatochnost. 2016; 17 (6): 413-417 [in Russian].*
3. *Saidova M. A. Modern approaches to the evaluation of left ventricular hypertrophy. Differential – diagnostic approaches. Terapevticheskiy arhiv. 2012; 4: 5-11[in Russian].*
4. *Kuppahally S. S, Akoum N, Burgon N. S, et al. Left atrial strain and strain rate in patients with paroxysmal and persistent atrial fibrillation: relationship to left atrial structural remodeling detected by delayed-enhancement MRI/ Circ. cardiovasc. Imaging. 2010;3:231-239. doi: 10.1161/circimaging.109.865683*
5. *Kleijn S. A, Aly M. F, Terwee C. B, van Rossum A. C. Three-dimensional speckle tracking echocardiography for automatic assessment of global and regional left ventricular function based on area strain. J.Am.Soc.Echocardiogr. 2011;24:314–321.doi:.2011.01.014.*
6. *Kouzu H, Yuda S, Muranaka A, et al. Left ventricular hypertrophy causes different changes in longitudinal, radial, and circumferential mechanics in patients with hypertension: a two-dimensional speckle tracking study. J Am Soc. Echocardiogr. 2011;24:192–9; doi: 10.1016/j.echo.2010.10.020*
7. *Szulik M, Sliwinska A, Lenarczyk R, Szymala M.3D and 2D left ventricular systolic function imaging-- from ejection fraction to deformation. Cardiac resynchronization therapy. ActaCardiol. 2015 Feb;70 (1):21-30.*
8. *Van Heerebeek L, Borbely A, Niessen H.W.M, Bronzwaer J. Myocardial structure and function differ in systolic and diastolic heart failure. Circulation. 2006;113:1966-73*
9. *Cioffi G, Senni M, Tarantini L, et al. Analysis of Circumferencial and Longitudinal Left Ventricular Systolic Function in Patients With Non-Ischemic Chronic Heart Failure and Preserved Ejection Fraction (from the CARRY-IN-HFpEF Study). Am J Cardiol 2012;109:383-9.*
10. *Petersen J. W, Nazir T. F, Lee L, Garvan C. S. Speckle tracking echocardiography-determined measures of global and regional left ventricular function correlate with functional capacity in patients with and without preserved ejection fraction. Cardiovascular ultrasound. 2013;11:20 doi: 10.1186/1476-7120-11-20*
11. *Elisabeth Kraigher-Krainer, Amil M. Shah, M. D, et al. Impaired Systolic Function by Strain Imaging in Heart Failure With Preserved Ejection Fraction. Journal of the American College of Cardiology. Vol. 63, No.5, 2014. Feb. 11, 2014:447–56 doi: 10.1016/j.jacc.2013.09.052*
12. *Park S. J, Miyazaki C, Bruce C. J, et al. Left ventricular torsion by two-dimensional speckle tracking echocardiography in patients with diastolic dysfunction and normal ejection fraction. Jam.Soc.Echocardiogr. 2008;21:1129–1137. doi: 10.1016/j.echo.2008.04.002*
13. *Stampehl M. R, Mann D. L, Nguyen J. S, et al. Speckle Stain Echocardiography Predicts Outcome in Patients with Heart Failure with both Depressed and Preserved Left Ventricular Ejection Fraction. Echocardiography 2015;32(1):71-8 doi: 10.1111/echo.1261*
14. *Aung S. M, Güler A, Güler Y, Huraibat A. Left atrial strain in heart failure with preserved ejection fraction. Herz. 2017 Apr;42(2):194-199 doi: 10.1007/s00059-016-4456*

Approved for publication: 12.04.2018