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Echocardiographic evaluation of myocardial structural and functional changes in patients with stage 5 chronic kidney disease before and after kidney transplantation

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Abstract

Introduction. *Chronic kidney disease, stage 5, leads to structural remodeling of the myocardium, and heart failure. Kidney transplantation promotes normalization of structural and functional parameters of the*

myocardium through reverse remodeling with an improvement of its systolic function.

Aim. *To evaluate structural and functional changes of the myocardium in patients before and after kidney transplantation, using echocardiography.*

Material and methods. *A retrospective cross-sectional study included 111 individuals of whom 36 patients underwent evaluation for kidney transplant waiting list placement program (Group I), and 51 patients received kidney transplants from deceased donors (Group II). Group III consisted of 24 individuals without kidney pathology. All patients underwent transthoracic two-dimensional echocardiography using the Phillips Epiq 7 device to determine the structural and functional parameters of the heart, including the use of speckle-tracking technique to assess longitudinal and circumferential myocardial deformation of the left ventricle.*

Results. *There were no statistically significant differences in transthoracic echocardiography results between patients in Group I and Group II. When compared to the parameters of patients in Group III, statistically significant differences were found in the following parameters: volume and volume index of the left atrium, end-diastolic volume index, left ventricular mass index, interventricular septum thickness and posterior wall thickness of the left ventricle, as well as diastolic function parameters (E/A). Patients in Group I and Group II had significantly higher values of left atrium diameter: 32 (26.0;38.0) mmHg and 31.0 (27.3;40.0) mmHg, respectively, (p_{1-2}=0.949), while in Group III this parameter value was 22.5 (20.8;25.3) mmHg (p_{1-3}<0.001, p_{2-3}<0.001). Correlation analysis revealed statistically significant correlations between left ventricular mass index and global circumferential strain (r=0.41, p=0.0027), as well as between E/e' ratio and left ventricular mass index (r=0.323, p=0.00197). It was found that*

after 3 months post kidney transplantation, there was a decrease in the left atrium diameter, volume, and volume index. The values of left atrium diameter immediately after kidney transplantation and after 3 months were 40 (32.5;45) mmHg and 35 (25.5;41.0) mmHg (p=0.049); those of the left atrium volume were 62.5 (50.0;77.3) and 51.5 (47.5;64.5) ml (p=0.03); and those of the left atrium volume index were 33.4 (29.3;40.2) and 28.3 (25.5;33.6) ml/m^2 (p=0.01) respectively.

Conclusions. *Patients with chronic kidney disease stage 5 have a high incidence of functional and structural abnormalities of the left heart chambers; left ventricular mass index positively correlates with E/e' and global circumferential strain. At 3 months after kidney transplantation, there was a slight positive trend manifested in the form of a decrease in left atrium diameter and a decrease in left ventricle volume. Further dynamic study of this group of patients in the long term after kidney transplantation is planned.*

Keywords: chronic kidney disease stage 5, hemodialysis, kidney transplantation, structural and functional changes of the myocardium, left ventricular myocardial deformation

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AH, arterial hypertension
CHD, coronary heart disease
CHF, chronic heart failure
CKD, chronic kidney disease
CKD S5, chronic kidney disease, stage 5

CVA, cerebrovascular accident
CVD, cardiovascular disease
CVS, cardiovascular system
DD, diastolic dysfunction
EchoCG, echocardiography
EDD, end-diastolic dimension
EDV, end-diastolic volume
EF, ejection fraction
eGFR, estimated glomerular filtration rate
ESV, end-systolic volume
GCS, global circumferential strain
GLS, global longitudinal strain
HD, hemodialysis
IVS, interventricular septum
IVSTh, interventricular septum thickness
KT, kidney transplantation
LA, left atrium
LV, left ventricle
LVH, left ventricular hypertrophy
LVMMI, left ventricular myocardial mass index
LVPWTh, left ventricular posterior wall thickness
PASP, pulmonary artery systolic pressure
PW, posterior wall
RRT, renal replacement therapy
SD, systolic dysfunction

Introduction

The impact of chronic kidney disease (CKD) on the cardiovascular system (CVS) is known. At CKD stage 5 (CKD S5), an increased stress on the heart caused by the pressure and volume overload leads to cardiac remodeling, manifested by structural and functional changes in the left atrium (LA), left ventricular hypertrophy (LVH) and myocardial fibrosis, which, in turn, leads to systolic and/or diastolic left ventricular failure. In addition, myocardial fibrosis causes electrical instability with a risk of sudden cardiac death [1, 2]. Earlier, M. Łukaszewski et al. (2018) showed in their study that patients with CKD S5 and cardiovascular disease (CVD) had an increased risk of death compared to the general population [3].

In the study by D. Banerjee et al. (2022), the signs of myocardial remodeling and left ventricular (LV) systolic (SD)/diastolic dysfunction (DD) were found in 74% of patients with CKD S5 [4]. In their study, X. Lu et al. (2003) found that each subsequent decrease in estimated glomerular filtration rate (eGFR) by 1 ml/min/ 1.73m^2 was associated with an increased risk of LVH and the development of SD and DD by 2% (OR: 1.02; 95% CI [1.02–1.02], p<0.001) [2].

Dialysis and kidney transplantation (KT) have been the only available treatment options for CKD S5. Compared to hemodialysis (HD), the advantage of KT is the normalization of cardiovascular system due to myocardial remodeling with an improvement of systolic function. KT has a positive effect on aortic elasticity, which reduces the LV afterload and may be one of the main mechanisms supporting LV reverse remodeling [3]. According to T. Zapolski et al. (2019), successful KT in patients with uremic cardiomyopathy initiates the process of LA remodeling. The decrease in the LA volume index is associated with a decrease in volume overload, and the reasons for the further decrease are likely related to the resolution of uremic toxemia and the absence of its negative effect on LA remodeling [5].

One of the promising methods for assessing myocardial contractility is to determine the values of myocardial deformation parameters using the Speckle-tracking method, which are the predictors of LV myocardial SD.

The objective was to assess structural and functional changes in the myocardium in patients before and after kidney transplantation using echocardiography.

Material and methods

The retrospective cross-sectional study included 111 subjects. Of these, 36 patients were examined according to the Program for placement on the KT waiting list (group I) at the Department of Kidney and Pancreas Transplantation of the N.V. Sklifosovsky Research Institute for Emergency Medicine in 2022; and 51 patients underwent KT from posthumous donors (group II). Group III consisted of 24 individuals without kidney pathology.

Clinical characteristics of patients in groups I and II are presented in Table 1.

Table 1. Clinical and demographic characteristics of patients in groups I and II

Parameters	Group I (n=36)	Group II (n=51)	p-value
Men/women, n (%)	14 (38.8)/22 (61.2)	28 (54.9)/23(45.1)	0.141*
Age, Me (Q1;Q3), years	45.5 (35.5;57.3)	49 (38.5;57.5)	0.617**
Arterial hypertension, n (%)	34 (94.4)	50 (98)	0.567*
CHD, n (%)	11 (30.55)	11 (21.56)	0.342*
CHF, n (%)	31 (86.1)	44 (86.27)	0.754*
Diabetes mellitus, type 1, n (%)	5 (13.8)	4 (7.8)	0.480*
Diabetes mellitus, type 2, n (%)	4 (11.1)	7 (13.7)	> 0.999*
History of CVA, n (%)	3 (8.3)	1 (1.9)	0.380*

Notes: * Pearson χ^2 test; ** Mann–Whitney U test. Data are presented as median and quartile values - Me (Q1;Q3); n, number of patients. CHD, coronary heart disease, CVA, cerebrovascular accident; CHF, chronic heart failure

As can be seen from Table 1, the patients of both groups who were on renal replacement therapy (RRT) were comparable in age and comorbid pathology rates. The most common diseases were arterial hypertension (AH) and CHF.

All patients underwent transthoracic two-dimensional echocardiography (EchoCG) using a Phillips Epiq 7 Unit to determine the

structural and functional parameters of the heart, using the Speckle-tracking technique to assess the longitudinal and circumferential strain of the LV myocardium.

To determine LV DD, we calculated the E/A (the ratio of the maximum velocity of early diastolic filling of the LV to the maximum velocity of LV filling in atrial systole) and E/e' (the ratio of the peak early diastolic transmitral flow velocity to the peak early diastolic lateral mitral annular velocity) using Doppler velocity measurements; E/A ratio <0.75 or >1.8 and E/e' >14 were designated as LV DD. Patients with LV interventricular septum (IVS) thickness or LV posterior wall (PW) thickness ≥12 mm were diagnosed with LVH.

AutoCMQ tool was used to estimate the deformation. Global Longitudinal Strain (GLS) > -20+-2 was designated as a decreased longitudinal strain. Global Circumferential Strain (GCS) > -30+-2 was designated as a decreased circumferential strain. Patients in group II were re-examined 3 months after KT.

Statistical processing

Statistical data processing was performed in the jamovi software, version 2.1.16 for the macOS Monterey operating system. The construction of a “heat map” of correlation relationships was performed using the pandas 1.5.3 and seaborn 0.12.2 software packages of the Python programming language, version 3.10. For statistical processing, the methods of parametric and nonparametric statistics were used. To determine the normality of the distribution, the Shapiro–Wilk test was used. Quantitative data are presented as median and interquartile range (Me (Q1;Q3)). Qualitative data are presented using absolute numbers and percentages (n (%)). Comparison of quantitative variables between the two groups was performed using the Mann–Whitney U test. Comparison

of quantitative parameters between the three groups was performed using the one-way Kruskal–Wallis analysis of variance. Pairwise post-hoc comparisons of differences in the study groups were performed using the Dwass-Steel-Critchlow-Fligner test. Qualitative data were compared using the χ^2 Pearson test for expected events (EEs) > 10; the χ^2 Pearson test with Yates' correction for continuity for EEs from 5 to 9; and Fisher's test for EEs < 5. Correlation analysis was performed using nonparametric Spearman test; the tightness of a linear correlation relationship was assessed using the Chaddock scale. For all criteria, a statistical significance level of 5% was used; statistical differences were recognized at $p < 0.05$. In case of post-hoc pairwise comparisons, the Bonferroni correction was used to determine statistical significance thresholds.

Results

The results of the transthoracic EchoCG of patients in the study groups are presented in Table 2.

Table 2. Echocardiography parameters in the study groups

EchoCG parameter	Group I (n=36)	Group II (n=51)	Group III (n=24)	p-value
LA volume Me (Q1;Q3), ml	60 (41.0;70.0)	50.5 (37.3;72.8)	32.0 (29.0;37.0)	**<0.001**** p_{1-2} =0.74* **p_{1-3} <0.001*** **p_{2-3} <0.001***
LA volume index, Me (Q1;Q3), ml/m^2	31.3 (24.5;35.9)	27.6 (21.8;37.9)	18.6 (16.8;20.0)	**<0.001**** p_{1-2} =0.5* **p_{1-3} <0.001*** **p_{2-3} <0.001***
LV ejection fraction, Me (Q1;Q3), %	60.0 (59.0;62.0)	62.0 (60.0;64.0)	61.0 (60.0;62.5)	**0.003**** **p_{1-2} =0.0033*** p_{1-3} =0.101* p_{2-3} =0.583*
EDV Index, Me (Q1;Q3), ml/m^2	48.5 (40.5;59.3)	43.5 (36.3;55.2)	38.5 (35.3;38.9)	**0.0002**** p_{1-2} =0.21* **p_{1-3} <0.001*** **p_{2-3} =0.017***

EDV, Me (Q1;Q3), ml	91.0 (68.5;111.0)	81.5 (68.0;108.0)	75.0 (67.5;77.0)	**0.01**** p_{1-2} =0.58* **p_{1-3} =0.004*** p_{2-3} =0.09*
ESV, Me (Q1;Q3), ml	35.0 (26.5;44.3)	30 (25.0;42.0)	30 (25.8;31.0)	**0.02**** p_{1-2} =0.25* **p_{1-3} =0.006*** p_{2-3} =0.656*
EDD, Me (Q1;Q3), cm	4.6 (4.0;4.9)	4.4 (4.0;4.9)	4.0 (3.8;13.1)	0.21** p_{1-2} =0.876* p_{1-3} =0.239* p_{2-3} =0.279*
LVMMI, Me (Q1;Q3), g/m ^{2}	104.0 (89.5; 140.0)	105.0 (82.3;121.0)	60.0 (55.0;60.0)	**<0.001**** p_{1-2} =0.855* **p_{1-3} <0.001*** **p_{2-3} <0.001***
IVSTh, Me (Q1; Q3), cm	1.4 (1.2;1.5)	1.4 (1.2;1.5)	0.9 (0.8;1.0)	**<0.001**** p_{1-2} =0.997* **p_{1-3} <0.001*** **p_{2-3} <0.001***
LVPWTh, Me (Q1;Q3), cm	1.0 (0.9;1.1)	1.0 (0.9;1.1)	0.8 (0.7;0.83)	**<0.001**** p_{1-2} =0.856* **p_{1-3} <0.001*** **p_{2-3} <0.001***
E/A, Me (Q1;Q3)	0.9 (0.7;1.1)	0.9 (0.7;1.2)	1.2 (1.0;1.4)	**0.0015**** p_{1-2} =0.991* **p_{1-3} =0.006*** **p_{2-3} =0.001***
E/e', Me (Q1;Q3)	6.8 (5.4;8.4)	7.5 (6.0;9.7)	5.7 (5.2;7.6)	0.268** p_{1-2} =0.268* p_{1-3} =0.171* **p_{2-3} =0.004***
PASP, Me (Q1;Q3), mm Hg	32.0 (26.0;38.0)	31.0 (27.3;40.0)	22.5 (20.8;25.3)	**<0.001**** p_{1-2} =0.949* **p_{1-3} <0.001*** **p_{2-3} <0.001***

Notes: Data are presented as median and quartile values: Me (Q1; Q3); n, number of patients, * Dwass-Steel-Critchlow-Fligner test; ** Kruskal-Wallis test. E/A, the ratio of the maximum velocity of early diastolic filling of the left ventricle to the maximum velocity of the left ventricle filling in atrial systole; E/e', the ratio of the peak early diastolic transmitral flow velocity to the peak early diastolic lateral mitral annular velocity; LVMMI, left ventricular myocardial mass index; EDV, end-diastolic volume; EDD, end-diastolic dimension; ESV, end-systolic volume; LV, left ventricle; LA, left atrium; PASP, pulmonary artery systolic pressure; LVPWTh, left ventricular posterior wall thickness; IVSTh, interventricular septum thickness

No statistically significant differences in the results of transthoracic echocardiography were seen between the patients of groups I and II.

When comparing these parameters with those of the patients in group III, there were revealed statistically significant differences in LA volume and volume index, EDV index, LVMMI, IVS thickness and LV PW thickness, as well as the parameters of the diastolic function (E/A).

LV EF was statistically significantly higher in patients of group II (62 (60.0;64.0) %, when compared to group I (p_{1-2}=0.0033)). Patients in groups I and II had LVH comparable to patients in the control group. In addition, they had statistically significantly higher PASP values: 32 (26.0;38.0) mmHg, and 31.0 (27.3;40.0) mm Hg (p_{1-2}=0.949), while in group III this figure was 22.5 (20.8;25.3) mm Hg (p_{1-3}<0.001, p_{2-3}<0.001), as well as a larger LA volume and LA volume index: 60 (41.0;70.0) ml and 50.5 (37.3;72.8) ml (p_{1-2}=0.74), 31.3 (24.5;35.9) ml/m^2 and 27.6 (21.8;37.9) ml/m^2 (p_{1-2}=0.5) compared with group III: 32.0 (29.0;37.0) ml (p_{1-3}<0.001, p_{2-3}<0.001) and 18.6 (16.8;20.0) ml/m^2 (p_{1-3}<0.001, p_{2-3}<0.001).

Table 3. Strain parameters and time to achieving the left ventricular maximum strain in the studied groups

Strain parameter	Group I (n=36)	Group II (n=51)	Group III (n=24)	p-value
GLS %, Me (Q1;Q3)	-13.1 (-15.5;-11.2)	-14.2 (-15.9;-12.0)	-21.1 (-21.1;-20.3)	**<0.001*** p_{1-2} =0.584* **p_{1-3} <0.001*** **p_{2-3} <0.001***
GCS %, Me (Q1;Q3)	-27.3 (-30.4;-21.4)	-28.9 (-32.0;-24.8)	-33.1 (-33.1;-31.0)	**<0.001**** p_{1-2} =0.253* **p_{1-3} <0.001*** **p_{2-3} <0.001***
Tε max GLS ms, Me (Q1;Q3)	322.0 (57.3;424.0)	247.0 (61.3;381.0)	3.5 (2.0;4.3)	**<0.001**** p_{1-2} =0.718* **p_{1-3} <0.001*** **p_{2-3} <0.001***

Tε max GCS ms, Me (Q1;Q3)	331.0 (92.5;483.0)	147.0 (77.8;456.0)	2.0 (1.0;3.0)	**<0.001**** p_{1-2} =0.736* **p_{1-3} <0.001*** **p_{2-3} <0.001***

Notes: Data are presented as median and quartile values: Me (Q1; Q3); n, number of patients, * Dwass-Steel-Critchlow-Fligner test; ** Kruskal-Wallis test. GCS, global circumferential strain; GLS global longitudinal strain; Tε max, time to achieve the maximum strain.

As can be seen from Table 3, no statistically significant differences between patients in groups I and II in speckle-tracking values of LV echocardiography parameters were found. Group III had statistically significant differences in all strain parameters (GLS, GCS), and the time to reach maximum LV strain.

Regression analysis of the main transthoracic echocardiography parameters

To identify statistically significant correlations, a “heat map” was constructed, shown in Fig. 1.

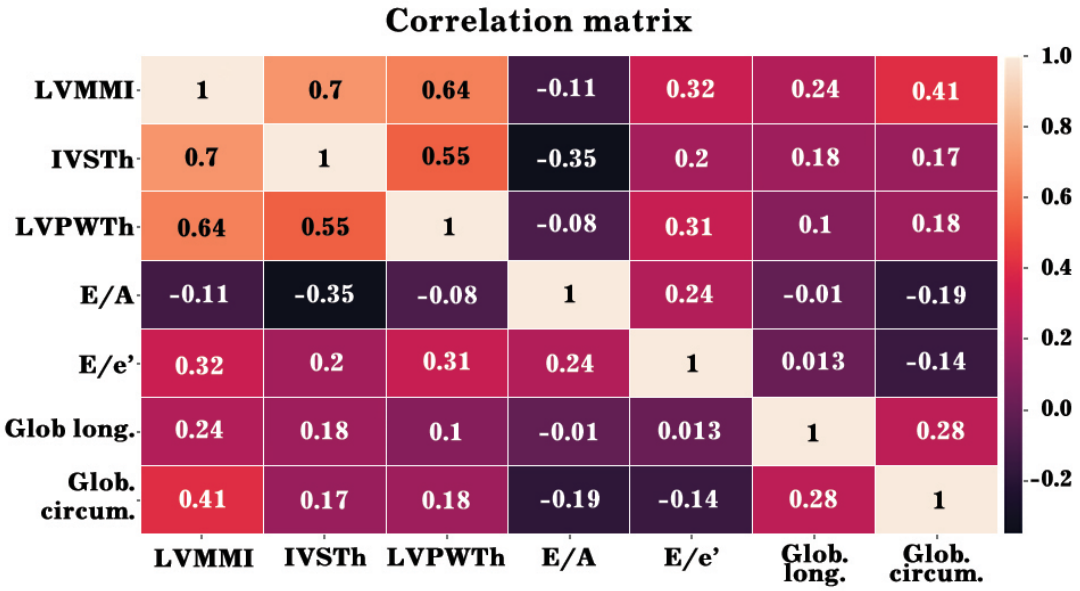

Fig. 1. Correlation analysis of echocardiography parameters in groups I and II

E/A, the ratio of the maximum velocity of early diastolic filling of the left ventricle to the maximum velocity of the left ventricle filling in atrial systole; E/e', the ratio of the peak early diastolic transmitral flow velocity to the peak early diastolic lateral mitral annular velocity; LVMMI, left ventricular myocardial mass index; Glob.long., global longitudinal strain; Glob.circum., global circumferential strain; LVPWTh, left ventricular posterior wall thickness; IVSTh, interventricular septum thickness

Statistically significant correlations were identified between LVMMI and the parameters of myocardial diastolic function (Fig. 2). When conducting regression analysis, a relationship was identified, described by the following equation:

$$Y_{E/e'} = 4.4897 + 0.0342 * X_{LVMMI}, \qquad (1)$$

where $Y_{E/e'}$ stands for the value of the diastolic function assessment; X_{LVMMI} stands for LV myocardial mass index.

The linear correlation relationship between the E/e' and LVMMI is weak (according to the Chaddock scale), statistically significant (r=0.323, p=0.00197).

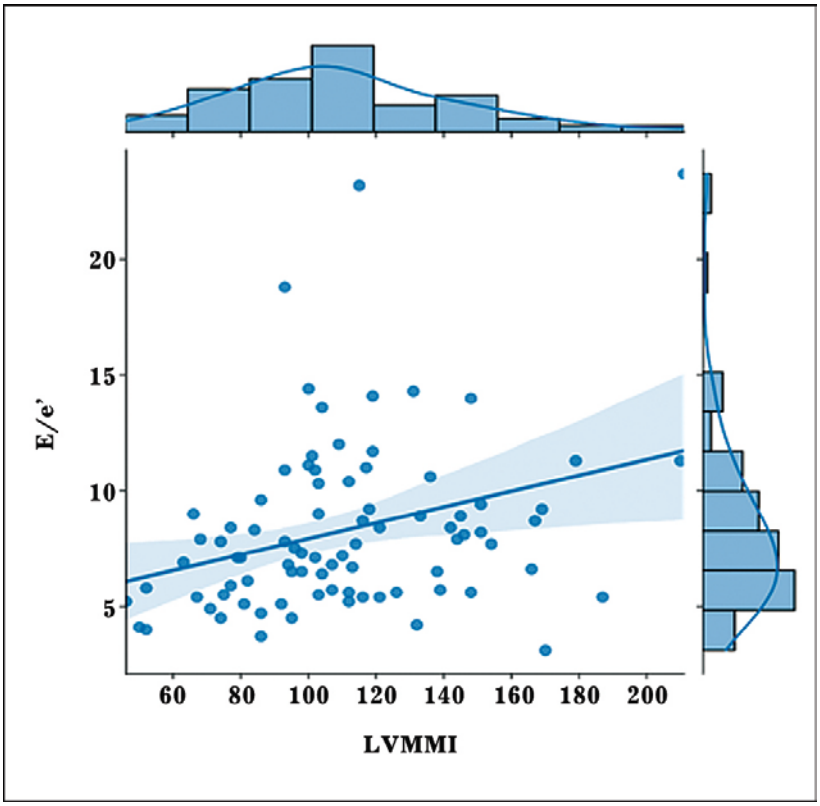

Fig. 2. Regression analysis of the E/e' parameter-to-left ventricular myocardial mass index relationship

E/e', the ratio of the peak early diastolic transmitral flow velocity to the peak early diastolic lateral mitral annular velocity

Also, during the correlation analysis, a relationship was identified between LVMMI and the general circumferential strain (GCS) of LV myocardium (Fig. 3).

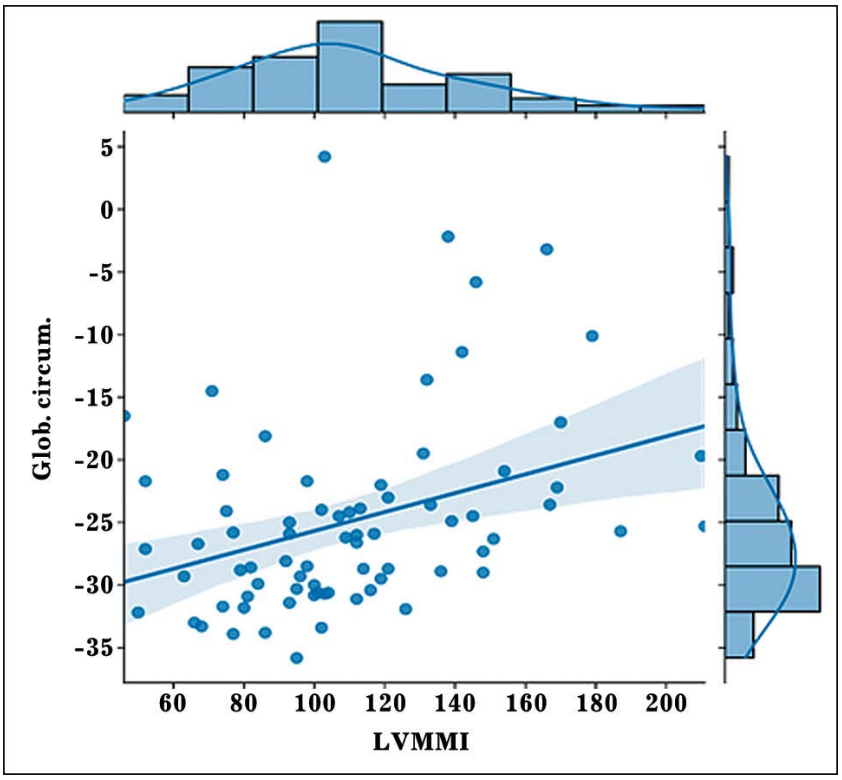

Fig. 3. Regression analysis of the relationship between the left ventricular myocardial mass index and the global circumferential strain

The observed relationship is described by the equation:

$$Y_{\text{global circumferential strain}} = 151.99 + 1.66 * X_{\text{LVMMI}}, \qquad (2)$$

where $Y_{\text{global circumferential strain}}$ is the total circumferential strain of the LV;

X_{LVMMI} is the LV myocardial mass index.

The linear correlation relationship between the global peripheral strain of the LV and LVMMI is medial (according to the Chaddock scale), statistically significant (r=0.41, p=0.0027).

Dynamic assessment of echocardiography parameters in patients after kidney transplantation

Over time, 3 months after KT, patients in group II underwent echocardiography with the LV strain assessment. The results are presented in table. 4.

Table 4. Dynamics of post-kidney-transplant echocardiography parameters in patients over 3 months

Parameter	On days 3–7 after KT	After 3 months	p-value**
LA volume, Me (Q1;Q3), mL	62.5 (50.0;77.3)	51.5 (47.5;64.5)	**0.030***
LA volume index, Me (Q1;Q3), mL/m^2	33.4 (29.3;40.2)	28.3 (25.5;33.6)	**0.010***
LV EF, Me (Q1;Q3), %	60.0 (58.5;61.0)	60.0 (60.0;63.0)	0.228
EDV index, Me (Q1;Q3), mL/m^2	50.0 (41.7;62.5)	51.5 (40.4;62.3)	0.783
EDV, Me (Q1;Q3), mL	97.0 (76.5;109.0)	95.0 (76.5;109.0)	0.753
ESV, Me (Q1;Q3), mL	38.0 (29.5;45.0)	36.0 (28.0;43.0)	0.414
EDD, Me (Q1;Q3), cm	4.8 (4.5;5.1)	4.5 (4.3;4.9)	0.310
LVMMI, Me (Q1;Q3), g/m^2	103.0 (94.5;125.0)	110.0 (99.0;117.0)	0.843
IVSTh, Me (Q1;Q3), cm	1.3 (1.2;1.4)	1.3 (1.2;1.4)	0.271
LVPWTh, Me (Q1;Q3), cm	1.0 (0.9;1.0)	1.0 (0.9;1.0)	0.671
E/A, Me (Q1;Q3)	1.0 (0.8;1.5)	1.0 (0.8;1.5)	0.194
E/e', Me (Q1;Q3)	8.3 (6.7;9.4)	7.8 (6.0;11.7)	0.610
PASP, Me (Q1;Q3), mm Hg	40.0 (32.5;45.0)	35.0 (25.5;41.0)	**0.049***
GLS, Me (Q1;Q3), %	14.1 (-16.3;-11.4)	15.4 (-16.8;-2.2)	0.366
GCS, Me (Q1;Q3), %	29.6 (-30.7;-25.3)	29.6 (-32.9;-28)	0.195
Tε max GLS, Me (Q1;Q3), ms	95.0 (57.0;403.0)	167.0 (83.8;344.0)	0.683
Tε max GCS Me (Q1;Q3), ms	342.0 (110.0;506.0)	406.0 (176.0;539.0)	0.689

Notes: Data are presented as median and quartile values: Me (Q1;Q3); n, number of patients. * Statistically significant differences; ** Mann-Whitney U test. EF, ejection fraction; Tε max, time to reach the maximum strain

At 3 months after KT, the decrease in LA volume and the decrease in PASP were statistically significant. The LA volume and LA volume index immediately after KT and after 3 months were 62.5 (50.0;77.3) and 51.5 (47.5;64.5) ml, respectively (p=0.03), 33.4 (29.3;40.2) and 28.3

(25.5;33.6) ml/m^2 (p=0.01). Also, a statistically significant difference was a decrease in PASP over the period of 3 months after KT making 40 (32.5;45) and 35 (25.5;41.0) mm Hg (p=0.049).

Discussion

CKD S5 leads to cardiac remodeling known as “uremic cardiomyopathy,” which reversal after KT remains controversial. In the study by Q. d'Hervé et al. (2023), the parameters of LV remodeling after KT did not change [6]. High values of LA volume parameters after KT remained in elderly patients with valvular heart defects, graft dysfunction, anemia, and hypertension. LA size and volume are reliable indicators of diastolic function and represent sensitive biomarkers of cardiovascular and renal outcomes in patients with CKD S5. The LA volume index reflects the adverse effect on the electrical activity of the heart in dialysis patients with LV DD and is a biomarker for stratifying ventricular repolarization disorders. The decrease in the LA volume index is associated with a decrease in volume overload; and the reasons for the further decrease are likely related to the resolution of uremic toxemia and the absence of its negative effect on LA remodeling. In the majority of patients undergoing RRT, the LVH with impaired diastolic function was detected, mainly in the form of impaired relaxation and preserved LV EF. This is due to a volume overload, electrolyte disturbances, and hypertension as risk factors influencing the risk of CVD in patients with CKD S5 [7]. According to various data, in CKD S5 the incidence of LVH, DD, and SD, respectively, ranged from 42 to 89%; 51–61%, and 24–36% [8–10]. In patients on HD and in the early postoperative period after KT, the GLS parameters were diffusely reduced, which indicated an early stage of diabetes development characterized by a slight decrease in GLS, DD and a preserved LV EF [11]. The reasons for these changes are

CKD S5 per se and many factors, including hypertension, heart failure, diabetes mellitus, etc. GLS is a predictor of all-cause mortality in patients with CKD S5. It is important that renal failure is associated with an early and subclinical impairment of LV systolic function, which is expressed by abnormal GLS, irrespective of the degree of renal function deterioration, and persistent, even despite successful KT [12–14].

In our study, patients in groups I and II, in contrast to the control group, had significant differences in the parameters reflecting the pumping function of the heart, the thickness of the LV walls, as well as LV myocardial strain. AH was diagnosed equally often in both groups. Both the patients on HD, and those after KT had CHF with normal LV EF and less negative GLS values compared to the control group. Similar data were demonstrated in the study by M. Ravera et al. (2018) [15].

In a study by T. Zapolski et al. (2019), the LA volume index slightly decreased at 3 months after KT [5]. As for the LV, the study by of N. Hawwa et al. (2015) demonstrated that in the long-term period after KT, LVEF improved in patients with LV dysfunction (increased from 41% to 50%; $p<0.0001$; $n=66$) and there were significant improvements in other parameters, including diastolic function, LV EDD, LVMMI, and PASP [16]. The study by D. Kim et al. (2023) also showed improvements in LV EF, LVMMI, and GLS at 6 months after KT [17].

In our study, there was a decrease in PASP and a decrease in LA volume, and there was a slight trend towards improvement in GLS, indicating initial signs of reverse myocardial remodeling. Other parameters at echocardiography echocardiography were at previous levels. Thus, in the first 3 months after KT, there remained a high risk of cardiovascular complications and death. It is likely that we will see further processes of reverse myocardial remodeling at a later term after KT. Further studies of this patient cohort are required.

Conclusions

1. In patients with stage 5 chronic kidney disease, the left ventricular myocardial hypertrophy is the most common structural defect, and the left ventricular diastolic dysfunction is the most common functional heart defect. An increased ratio of the peak early diastolic transmitral flow velocity to the peak early diastolic lateral mitral annular velocity (E/e') is a strong independent predictor of increased left ventricular myocardial mass index.

2. Patients with stage 5 chronic kidney disease are characterized by chronic heart failure with preserved left ventricular ejection fraction.

3. The speckle-tracking technique can be used to identify early disturbances in systolic function in patients with stage 5 chronic kidney disease and a preserved left ventricular ejection fraction.

4. At 3 months after kidney transplantation, myocardial changes characteristic of stage 5 chronic kidney disease persist, which is associated with an increased risk of cardiovascular complications in the early post-transplantation period. Meanwhile, there is a slight positive trend manifested as a decrease in pulmonary artery systolic pressure and reverse remodeling of the left atrium (a decrease in the volume and volume index of the left atrium).

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