CARDIOLOGY

LEFT VENTRICULAR DIASTOLIC DYSFUNCTION AND TRANSMITRAL BLOOD FLOW PARAMETERS IN PATIENTS AFTER COVID-19

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ABSTRACT

Background. *People who previously had COVID-19 infection have an increased risk of developing cardiovascular diseases. Left ventricular diastolic dysfunction is an early marker of the development of cardiac pathology. Its early detection is important for the adequate therapy order and dynamic monitoring of patients. In this regard, it seems relevant to study the effect of a recent COVID-19 infection on the left ventricular diastolic function and transmitral blood flow parameters in apparently healthy individuals without clinical and instrumental signs of cardiovascular pathology.*

The aim of the study. *To assess the changes in the diastolic and systolic function of the left ventricle, its anatomical parameters and transmitral blood flow parameters in two groups of apparently healthy individuals: those who had and those who had not COVID-19 infection.*

Materials and methods. *Transthoracic echocardiography was performed according to the standard technique and its results were analyzed in 66 examined patients who were recognized as apparently healthy according to the results of regular comprehensive clinical and instrumental studies. The first group included 30 individuals who underwent an echocardiographic study before or during the COVID-19 pandemic, but did not have a coronavirus infection; the second group consisted of 36 people who recovered from COVID-19. The indicators of the presence of left ventricular diastolic dysfunction and the transmitral blood flow parameters were assessed. The study was approved at a meeting of the Medical Ethics Committee under the Ministry of Health of the Republic of Karelia and of Petrozavodsk State University (Minutes No. 47 of 01.11.2023).*

Results. *The frequency of the left ventricular diastolic dysfunction did not differ in the first and second groups of patients. Statistically significant differences were recorded in the average flow deceleration time for both early and late filling of the left ventricle in people who had and did not have COVID-19 infection. A change in the phase structure of the transmitral blood flow may be an early manifestation of intracardiac hemodynamic disorders in people who have recovered from COVID-19.*

Key words: *COVID-19, diastolic function, left ventricle, transmitral blood flow, echocardiography*

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ДИАСТОЛИЧЕСКАЯ ДИСФУНКЦИЯ ЛЕВОГО ЖЕЛУДОЧКА И ПАРАМЕТРЫ ТРАНСМИТРАЛЬНОГО КРОВОТОКА У ЛИЦ, ПЕРЕНЁСШИХ COVID-19

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РЕЗЮМЕ

Обоснование. *У лиц, перенёсших инфекцию COVID-19, имеется повышенный риск развития заболеваний сердечно-сосудистой системы. Диастолическая дисфункция левого желудочка является ранним маркером развития кардиологической патологии. Её своевременное выявление имеет важное значение для назначения адекватной терапии и динамического наблюдения за пациентами. В связи с этим представляется актуальным исследование влияния перенесённой инфекции COVID-19 на диастолическую функцию левого желудочка и показатели трансмитрального кровотока у практически здоровых лиц при отсутствии у них клинико-инструментальных признаков сердечно-сосудистой патологии.*

Цель исследования. *Оценка изменений диастолической и систолической функции левого желудочка, его анатомических параметров и показателей трансмитрального кровотока в двух группах практически здоровых лиц: перенёсших и не перенёсших инфекцию COVID-19.*

Материалы и методы. *Проведена трансторакальная эхокардиография по стандартной методике и проанализированы её результаты у 66 обследованных, признанных практически здоровыми по результатам регулярных комплексных клинико-инструментальных исследований. В первую группу были включены 30 лиц, прошедших эхокардиографическое исследование до пандемии COVID-19 или в период пандемии, но не болевшие коронавирусной инфекцией; вторую группу составили 36 лиц, переболевшие COVID-19. Оценивались показатели, свидетельствующие о наличии диастолической дисфункции левого желудочка, и параметры трансмитрального потока крови. Исследование одобрено на заседании Комитета по медицинской этике при Министерстве здравоохранения Республики Карелия и ФГБОУ ВО «Петрозаводский государственный университет» (протокол № 47 от 11.01.2023).*

Результаты. *Частота выявления диастолической дисфункции левого желудочка не отличалась в первой и второй группах пациентов. Зарегистрированы статистически значимые различия в средних показателях времени замедления потока как раннего, так и позднего наполнения левого желудочка у лиц, перенёсших и не перенёсших инфекцию COVID-19. Изменение фазовой структуры трансмитрального кровотока может быть ранним проявлением нарушений внутрисердечной гемодинамики у лиц, переболевших COVID-19.*

Ключевые слова: *COVID-19, диастолическая функция, левый желудочек, трансмитральный кровоток, эхокардиография*

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RELEVANCE

The coronavirus (COVID-19) pandemic has provided some new conditions and serious new challenges in the diagnosis and treatment of various diseases. Studies and clinical observations have established that the respiratory tract and lungs are not the only targets for coronavirus; the cardiovascular system is also frequently involved in the pathological process [1-3]. Available publications and medical reports, as well as experts of the World Health Organisation show statistics of higher morbidity and mortality of elderly people with various cardiological diseases against the background of a new infection [4]. Therefore, the cardiovascular implications of COVID-19 continue to be actively under discussion [5].

Patients with coronavirus infection have an increased risk of thrombotic events, including myocardial infarction and pulmonary embolism, myocarditis and other cardiac pathologies [6, 7]. The pathophysiological mechanisms of cardiomyocyte injuries in COVID-19 may be hypoxia, thrombotic complications, side effects of pharmacotherapy, and hemodynamic disturbances in the lesser circulation/pulmonary circulation [8–11].

The majority of studies that have been undertaken in this area have involved predominantly elderly patients, many of whom have previous cardiovascular disease, as well as chronic diseases of other organs [2, 6, 12]. However, there is an evidence of cardiac lesions during COVID-19 in patients without previous cardiovascular disease, which has been obtained from clinical studies, magnetic resonance imaging and echocardiography (EchoCG) [1, 10, 13].

The determination of left ventricular diastolic dysfunction (LV DD) is one of the most used and informative methods to diagnose cardiac lesions of various etiologies at early stages [11, 14]. It is observed in almost all cardiac disorders and often precedes the development of systolic dysfunction, changes in LV morphometric parameters, as well as clinical signs of chronic heart failure syndrome.

Three different types of diastolic dysfunction can be categorised, differing primarily by the degree of its progression – relaxation disorder (type 1), pseudonormal variant (type 2) and restrictive variant (type 3). Assessing of early diastolic disorders in the left ventricle during EchoCG, both morphometric parameters of the left ventricle and left atrium in M- and B-modes and parameters of transmittal blood flow and mitral valve fibrous ring motion in spectral Doppler analysis and tissue Doppler modes should be performed [15–17].

At the same time, as shown in several recent studies, LV DD can be diagnosed in patients without clinical or instrumental signs of cardiac pathology (so-called subclinical dysfunction) [11, 18, 19]. In particular, such changes can be observed in a proportion of patients who have had a coronavirus infection [15]. In COVID-19, diastolic dysfunction can be considered as an early marker of changes in intracardiac haemodynamics as a result of infection in the absence of anamnestic, clinical and instrumental data suggestive of cardiac pathology. Consequently, the LV DD detection may be an important part of a comprehensive assessment of cardiac changes during EchoCG in reconvalescents for risk stratification and development of a more targeted treatment approach [5, 16, 19–21]. One of the most informative indicators for detecting early hemodynamic disorders of non-specific genesis are the parameters of the transmittal blood flow, in particular, the ratio of E/A peaks [16, 19].

However, previous echocardiographic follow-up data are important when assessing the impact of coronavirus infection on the cardiovascular system in previously healthy patients, as pointed out by some authors [1]. Besides, it should be confirmed that they have no cardiological pathology based on a sufficiently complete clinical and instrumental examination. The majority of studies devoted to the determination of LV DD in patients with or after COVID-19 infection have performed echocardiographic studies only when the disease has been diagnosed. This prevents the identified changes from being reliably correlated with the coronavirus infection factor. As a result, it is of interest to study the effect of COVID-19 infection on LV diastolic function in practically healthy individuals with previous EchoCG data in order to detect early abnormalities of intracardiac haemodynamics.

In 2018–2019, before the pandemic of coronavirus infection, we evaluated the presence and degree of LV DD in patients with arterial hypertension, while a group of essentially healthy individuals was examined with transthoracic EchoCG [22]. In all patients, parameters of LV DD were determined, including determination of transmitral blood flow parameters. They were also followed up regularly at our medical facility: this group of individuals formed the basis for the present study.

THE AIM OF THE STUDY

To assess the changes in the diastolic and systolic function of the left ventricle, its anatomical parameters and transmitral blood flow parameters in two groups of apparently healthy individuals: those who had and those who had not COVID-19 infection.

METHODS

The study was conducted on the basis of the Department of Ultrasound Diagnostics of the Clinical Hospital «RZhD-Meditsina» of Petrozavodsk and the Department of Radiation Diagnostics and Radiation Therapy with a course of critical and respiratory medicine of Petrozavodsk State University.

In the period from 2019 to 2022, we performed transthoracic EchoCG according to the standard technique and analysed its results in 66 individuals considered practically healthy according to the annually conducted complex clinical and instrumental examination in the conditions of the therapeutic hospital and polyclinic. The study

participants signed a voluntary informed consent for an ultrasound scan.

All those examined are employed as locomotive drivers or driver's assistants in railway transport and therefore undergo an annual medical examining board to determine their job suitability. Examination of these individuals includes clinical and biochemical analyses, electrocardiography (ECG), daily ECG monitoring, transthoracic EchoCG, triplex scanning of brachiocephalic vessels, integral body rheography, examination by narrow specialists, and, if necessary, coronarography or stress EchoCG (in a central departmental clinic). According to the results, no cardiovascular pathology was recorded in all examined individuals.

All those who entered the study were male and their ages ranged from 21 years to 59 years, with a median of 44 years and a mean age of 43.5 years. The control group (group 1) included 30 individuals who underwent transthoracic EchoCG examination before the COVID-19 pandemic, between 2019 and 2020, and during the pandemic, between 2021 and 2022, but who did not have COVID-19. Group 2 consisted of 36 individuals who had experienced coronavirus infection and were examined between 2021 and 2022. The groups were comparable in age: the minimum age in the group 1 was 21 years, the maximum was 56 years, the mean was 43.3 years, and the median was 45.5 years. In the group 2, the minimum age was 31 years, the maximum was 59 years, the mean was 43.9 years, and the median was 43 years.

Confirmation of the COVID-19 disease in all patients of the group 2 was performed by examination of the patient's history (interview after EchoCG), data of outpatient and inpatient examination records (presence of the diagnosis of coronavirus infection), results of polymerase chain reaction (PCR) study and enzyme-linked immunosorbent assay (ELISA) [23]. Positive PCR test results were available in 100 per cent of the group 2 and ELISA test results in 45 per cent. Individuals with a positive ELISA test and no history of positive PCR, anamnestic and documentary evidence of coronavirus infection were not included in the study. The severity of the disease, as well as the assessment of the presence of lung lesions, was not analysed, as the majority of patients (61 %) were treated as outpatients, and some of them lacked the necessary results, such as SpO_2 level, spiral computed tomography findings, etc.

The absence of a coronavirus infection history was determined according to the results of anamnesis collection, data from outpatient and inpatient records, conclusions of regular medical examinations (2 to 4 times a week) for admission to work in the period preceding the examination, negative results of PCR and ELISA tests.

Transthoracic echocardiographic study with Doppler analysis was performed according to the standard technique of the American Society of Echocardiography (ASE, American Society of Echocardiography) using ACUSON S1000 HELX Evolution series devices (Siemens, Germany) in 2021–2022 and VIVID-3 Expert (General E lectric Healthcare, USA) in 2018-2019 with the determination of a number of generally accepted morphofunctional parameters [16, 19]. To assess LV diastolic function, transmitral flow was studied by pulsed-wave Doppler analysis from apical access in a 4-chamber section with the control volume located at the level of the mitral valve leaflet ends (according to ASE 2009 and 2016 recommendations).

In our study, such morphometric parameters of the heart were evaluated as the left ventricular end-diastolic diameter (LV EDD) and left atrium end-systolic diameter (LA ESD), left ventricular end-diastolic volume (LV EDV) and its index (to body surface area (BSA)), left atrium end-systolic volume (LA ESV) and its index (to BSA), interventricular septum thickness and left ventricle posterior wall in the diastole (T_{ivs} and T_{lvpw}, respectively), left ventricular mass (LVM). The values of ejection fraction (EF) and shortening fraction (SF) in per cent calculated by Simpson's formula in B-mode [19] were assessed as indices of left ventricular systolic function. The following indicators were taken as normal values: 55 % or more for EF, 27 % or more for SF.

In addition, if morphometric indices deviated from the standard, their ratio was determined to detect the presence and type of left ventricular remodelling. If signs of left ventricular myocardial hypertrophy were observed, the LVM and the index of left ventricular relative myocardial thickness (RMT) were used to assess its nature. The mass of the myocardium was determined according to the formula recommended by the ASE: $LVM\ (g) = 0.8 \times (1.04 \times (T)_{ivs} + LV\ EDD + T_{lvpw})^3 - (LV\ EDD)^3 + 0.6$, the relative thickness was calculated using the formula: $RMT = (T_{ivs} + T_{lvpw}) / LV\ EDD$ in M-mode under the control of B-mode. According to the results of the examination, the following types of LV geometry disorders were distinguished: concentric hypertrophy, concentric remodeling and eccentric type of hypertrophy.

From the parameters of the transmittal blood flow, the following were estimated: the maximum flow rate of rapid (early) filling (E, m/s); the maximum flow rate of slow (late) filling (A, m/s); the rate ratio E/A; the acceleration time of the rapid filling phase (AT_E, ms); the deceleration time of the rapid filling phase (DT_E, ms). We also determined the following indices, which are not usually used in studies: the acceleration time of the slow filling phase (AT_A, ms); the deceleration time of the fast filling phase (DT_A, ms). The parameters of the mitral valve ring movement indicated in the 2016 recommendations were not taken into account by us, since they were not determined in patients examined on the VIVID-3-Expert ultrasound machine (General Electric Healthcare, USA) due to the lack of tissue Doppler analysis mode in it. In our opinion, this is not a critical shortcoming of the study, as it is illogical to expect the presence of type 2 or 3 LV DD in the patients with no clinical or instrumentally detectable signs of cardiovascular pathology. In initial (subclinical) disorders of intracardiac haemodynamics, type 1 LV DD may be observed; the estimated indices are sufficient for its detection.

The study was conducted by double-blind sampling. If patients met the requirements for selection for the study (the assessment was performed by a specialist not involved in performing the EchoCG), they were interviewed

and their medical records were reviewed by a physician after the EchoCG. Accordingly, the patient's history was known to the clinician only after all indicators had been assessed and a conclusion had been formed. Patients were also unaware of their participation in the study and which group they belonged to prior to the survey. The analysis of individual dynamics of echocardiographic indices for each patient was not performed since the examined patients underwent examinations in different time periods at various diagnosticians, so the obtained data will have low validity. Here it is necessary to consider the operator's error during measurements, which can be critical in case the estimated parameter exceeds the normal values during individual assessment. During the statistical processing of group indicators it was considered by us using the determination of the standard confidence interval.

We have performed calculations of average values of the assessed indicators by groups and their statistical assessment. Standard tools and formulas of the MS Excel spreadsheet processor from the Microsoft Office 2019 software package (Microsoft Corp., USA) were used for statistical processing. The statistical assessment of all data had a normal distribution (the test for normal distribution was performed using the Shapiro – Wilk criterion). The parametric Student's *t* test was chosen for comparison of mean values; differences in the values of indicators were considered statistically significant at $p < 0.05$. The hypothesis of equality of variance was pre-tested in checking the hypothesis of position (hypothesis of equality of mean values in two samples) using Student's criterion. For this purpose, Fisher's criterion (φ*) was used to compare the indices of the same sample measured in different conditions; differences in the values of indices were considered statistically significant at $p < 0.05$. These results present the data in the form of mean values of the estimated indices with a standard error of mean square.

RESULTS

We obtained the following results during the assessment of morphometric indices at EchoCG, as presented in Table 1. In the groups 1 and 2 of the examined patients, the indicators of LA ESD, as well as LA ESV and its indexed values were almost the same; the differences were not statistically significant ($t > 0.05$). However, the maximum values of these indices were slightly outside the normal range in only one COVID-19 non-diseased and 3 overdiseased patients, respectively.

When left ventricular parameters were assessed, the mean left ventricular EDD values in the group 1 were 50.8 ± 3.3 mm and in the group 2 were 49.8 ± 2.4 mm; the differences were also statistically non-significant ($t > 0.05$). The same results were obtained when compar-

TABLE 1

MORPHOMETRIC AND FUNCTIONAL INDICES OF THE LEFT VENTRICLE AND LEFT ATRIUM IN THE TWO GROUPS OF PATIENTS STUDIED

Indicators	Group 1 (*n* = 30)	Group 2 (*n* = 36)	t-test
LA ESD, mm	35.6 ± 3.3	36.6 ± 2.8	0.25
LA ESV, ml	53.1 ± 6.2	56.6 ± 5.7	0.31
LA IESV, ml/m^2	27.9 ± 2.5	29.8 ± 2.7	0.23
LV EDD, mm	50.8 ± 3.3	49.8 ± 2.4	0.18
LV EDV, ml	122.7 ± 27.8	117.15 ± 24.5	0.45
LV IEDV, ml/m^2	64.5 ± 3.2	61.4 ± 3.9	0.41
$T_{ivs,}$ мм	10.6 ± 1.3	11.1 ± 1.2	0.74
$T_{lvpw,}$ mm	10.3 ± 1	10.3 ± 0.9	0.65
ILVM g/m^2	84.3 ± 5.3	90.2 ± 6.9	0.53
RMT	0.42 ± 0.04	0.42 ± 0.04	0.17
LVEF average value, %	64.0 ± 4	65.3 ± 4.8	0.25
LVSF average value, %	35.1 ± 4.1	36.3 ± 3.9	0.79

Note. LA IESV – indexed left atrium end-systolic volume; LV IEDV – indexed left ventricular end-diastolic volume; ILVM – indexed left ventricular myocardial mass.

ing mean LV end-diastolic volumes and their indexed values – 64.5 ± 3.2 ml/m^2 for the group 1 and 61.4 ± 3.9 ml/m^2 for the group 2.

The analysis of the average values of the T_{ivs} in the groups 1 and 2 also obtained almost identical results. At the same time, signs of minor myocardial hypertrophy of the IVS were detected in three examined patients of the group 1 (T_{ivs} = 12 mm) and in 5 individuals from the group 2 (T_{ivs} = 12–13 mm). When estimating the average value of LVPW diastolic thickness in the group 1, the indicator was 10.3 ± 1 mm, in the group 2 – 10.3 ± 0.9 mm ($t > 0.05$).

LV myocardial mass indices did not differ statistically significantly in the groups 1 and 2 and were within normal values; the average values of RMT in the groups 1 and 2 were almost identical. At the same time, signs of LV remodeling were detected in 3 (10 %) examined from the group 1, of them by type of concentric – in 2 cases, by type of concentric hypertrophy – in 1 case. In the group 2, changes in LV geometry were detected in 7 (19 %) patients, according to the type of concentric remodeling – in 4 examined patients, according to the type of concentric hypertrophy – in 2 cases. Criterion φ* = 1,084, the difference in the frequency of detection of the sign is not statistically significant. In general, deviations of anatomical parameters from the norm out of 66 examined patients were noted in 6 (9 %) individuals who did not have COVID-19 and 8 (12 %) individuals who had coronavirus infection; the difference is not statistically significant (φ = 0.218).

As for the assessment of LV systolic function, the average EF index (Table 1) in the examined groups 1 and 2 were within normal values; the differences were not statistically significant ($t > 0.05$). Similar results were obtained when calculating the SF index, while the minimum values also did not exceed the normal ones.

When evaluating the parameters of the transmittal flow, we obtained the results presented in Table 2; the indicators are presented as an average value with a standard deviation. Differences in the average values of peak E in the groups 1 and 2 were not statistically significant ($t > 0.5$), while indicators above the age norm were noted in 6 examined patients who did not have COVID-19 and in 7 patients who had COVID-19; criterion φ* = 0.556. The calculated average values of AT_E also did not differ significantly in the groups 1 and 2 ($t > 0.05$); this indicator was not taken into account to determine the presence and type of LV DD. The average values of DT_E were 115.1 ± 45.2 ms (group 1) and 84.2 ± 26.3 (group 2); deviation from normal values was detected only in 1 individual who did not have COVID-19. The difference in indicators for AT_E is not statistically significant ($t > 0.05$), for DT_E it is statistically significant ($t < 0.05$).

For A peak, the calculated average values in the groups 1 and 2 were almost the same ($t > 0.05$). The AT_A average values in those who had and did not have coronavirus infection were quite close ($t > 0.5$), while for the DT_A they differed significantly: 115.1 ± 45 ms (group 1) and 84.22 ± 2.3 ms (group 2), respectively. There are no generally accepted normal values for these indicators, so it is not possible to say whether they deviate from the normal values. The difference in the groups in the first case is not statistically significant ($t > 0.05$), in the second – statistically significant ($t < 0.05$).

When assessing the E/A ratio in the groups 1 and 2, the average values were similar ($t > 0.05$), while changes characteristic of LV DD according to type 1 were detected in 18 of the 66 (27 %) examined: 9 (30 %) patients of the group 1 and also in 9 (25 %) individuals of the group 2; the differences obtained in the two groups are not statistically significant (φ = 0.453).

TABLE 2

LEFT VENTRICULAR DIASTOLIC DYSFUNCTION AND TRANSMITTAL BLOOD FLOW PARAMETERS IN TWO GROUPS OF PATIENTS

Parameters	Group 1 (n = 30)	Group 2(n = 36)	t-test
E average value, m/s	0.82 ± 0.15	0.83 ± 0.16	0.89
AT_E average value, ms	60 ± 20.5	78.6 ± 13.5	0.31
DT_E average value, ms	115.1 ± 45.2	84.2 ± 26.3	0.02
A average value, m/s	0.63 ± 0.11	0.64 ± 0.1	0.76
AT_A average value, ms	82.1 ± 14.7	78.6 ± 13.5	0.74
DT_A average value, ms	115.1 ± 45	138.8 ± 29.9	0.01
E/A	1.35 ± 0.28	1.32 ± 0.28	1.32

DISCUSSION

Thus, in our study, there were no statistically significant differences in the frequency of detection of signs of LV DD in the two groups of examined patients. This does not suggest the existence of a correlation between the development of dysfunction and COVID-19 infection. However, when evaluating the results of our study, it is necessary to take into account certain limitations of the sample and the fact that measurements at different points in time for the diagnosis of LV diastolic dysfunction can lead to potential heterogeneity of results [11].

We identified a fairly significant percentage (27 %) of LV diastole disorders in the control group of the examined patients. Consideration and analysis of the causes of LV diastole disorders in echocardiographic examination of practically healthy individuals, demonstrated in our previous study and a number of other works, are beyond the scope of this article [18, 20, 24]. In this case, it is advisable to talk about the so-called subclinical LV DD, which can be an early sign of disorders of intracardiac hemodynamics and subclinical systolic dysfunction, which is not detected by traditional echocardiographic parameters [20, 25].

We have identified statistically significant differences in the average time of slowing down the flow of both early and late filling of the left ventricle in individuals who have and have not had COVID-19 infection. No such differences were found in other parameters of the transmittal flow. This may indicate the initial manifestations of a violation of the phase structure of the transmittal flow in the group 2 of examined patients. At the same time, patients who have had coronavirus infection have signs indicating some statistically significant differences from the control group in the phases of both active and passive relaxation of the left ventricle. Thus, during the period of active filling, there was a shortening of the time of deceleration of the flow of DT_E compared with the group 1 (although its indicators were within the normal range for most of the examined patients), which indicates an increase in LV filling pressure. In the phase of passive filling, an elongation of the DT_A index was noted, which characterizes a deceleration of this process.

The clinical significance of the revealed differences in the parameters of transmittal blood flow in patients with COVID-19 compared with the control group is currently unclear, however, they may indicate initial violations of intracardiac hemodynamics. It cannot be excluded that they are the result of the damaging effect of the COVID-19 virus, which, according to a number of studies, has an affinity to the myocardium and endocardium, and myocardial damage can be detected even after recovery [25–27]. For a more accurate assessment and correlation of the results obtained with the COVID-19 factor, a promising study is needed to determine the parameters of the transmittal blood flow and the movement of the fibrous ring of the mitral valve in the mode of tissue Doppler sonography in the examined group 2.

CONCLUSIONS

Signs of left ventricular diastolic dysfunction were detected in two groups of examined patients, while the frequency of its detection did not differ statistically significantly in those who had and had not suffered COVID-19 infection. In patients with COVID-19, certain statistically significant differences in the phase structure of the transmittal flow were registered compared with the control group, which may be a marker of early disorders of intracardiac hemodynamics. There were no statistically significant differences in the estimated morphometric parameters and indicators of systolic function of the left ventricle in the examined patients with a history of COVID-19 infection and without it.

Conflict of interest

The authors of this article declare the absence of a conflict of interest.

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