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Динамика сократительной функции левого предсердия у больных с ишемической митральной регургитацией

С. И. Мусаев, Э. Ф. Курбанов

Научный центр хирургии имени М. А. Топчибашева, г. Баку, Азербайджанская Республика

Dynamics of contractile function of the left atrium in patients, suffering ischemic mitral regurgitation

S. I. Musayev, E. F. Gurbanov

Scientific Centre of Surgery named after M. A. Topchibashev, Baku, Azerbaijani Republic

Реферат

Цель. Оценка механической функции левого предсердия у больных с ишемической митральной регургитацией с использованием технологии векторного анализа скорости движения эндокарда.

Материалы и методы. В проспективное когортное нерандомизированное исследование включены 107 пациентов в возрасте (56 ± 7,5) года, из них 96 (89,7%) мужчин. Критерии отбора: I-III степень ишемической митральной регургитации на эхокардиографии, ангиографически выявленная ишемическая болезнь сердца, требующая хирургической реваскуляризации, синусовый ритм с частотой сердечных сокращений от 60 до 89 в 1 мин, улучшенная эхокардиографическая визуализация эндокарда левого предсердия.

Результаты. Показатели механической функции левого предсердия снижаются пропорционально степени тяжести ишемической митральной регургитации. Продольная деформация и скорость деформации левого предсердия отражают связь с ишемической митральной регургитацией больше, чем обычные индексы, используемые для оценки геометрии левого предсердия. Полученные данные свидетельствуют о сопоставимых ультраструктурных изменениях предсердия, возникающих при хронической объемной перегрузке митральной регургитации от II степени и выше. Изменения и скорость деформации предсердий могут быть связаны с тяжестью регургитации.

Выводы. Значения механической функции левого предсердия связаны с ишемической митральной регургитацией и зависят от механического ремоделирования левого предсердия. Изучение динамики механической функции левого предсердия у больных с митральной регургитацией может быть перспективным и полезным при оценке ее гемодинамической значимости и выборе хирургического подхода для дополнительного вмешательства на митральном клапане.

Ключевые слова: ишемическая митральная регургитация; сократительная функция левого предсердия; эхокардиография; ультразвуковое исследование.

Abstract

Objective. Estimation of mechanical function of the left atrium in patients, suffering an ischemic mitral regurgitation, using technology of the vector analysis of the endocardium movement speed.

Materials and methods. Into prospective cohort of non-randomized investigation 107 patients ageing (56 ± 7.5) yrs old, 96 (89.7%) of them are men, were included. There were following criteria of selection: the Degrees I-III of ischemic mitral regurgitation by echocardiographic data, angiographically revealed an ischemic heart disease, demanding surgical revascularization, the sinus rhythm with the heart rate frequency from 60 to 89 in 1 minute, the improved echocardiographic visualization of the left atrium endocardium.

Results. The indices of mechanical function of the left atrium are lowering in proportion to degree of severity of the ischemic mitral regurgitation. Longitudinal deformity and speed of the left atrium deformity reflects connection with the ischemic mitral regurgitation more, than conventional indices, applied for estimation of the left atrium geometry. The data obtained witnesses thet comparable ultrastructural changes in atrium, occurring in chronic volume overload of mitral regurgitation from Degree II and higher. The changes and velocity of the atriums deformity may be associated with severity of regurgitation.

Conclusion. Significance of the left atrium mechanical function is associated with the ischemic mitral regurgitation and depends on mechanical remodeling of the left atrium. Studying of dynamics of the left atrium mechanical function in patients with mitral regurgitation may appear perspective and beneficial while doing estimation of its hemodynamical significance and choice of surgical approach as additional intervention on a mitral valve.

Keywords: ischemic mitral regurgitation; contractile function of the left atrium; echocardiography; ultrasound investigation.

Introduction

The issues of ischemic mitral regurgitation (IMR) remains most relevant in the treatment of patients with coronary heart disease (CHD), since even a small degree of IMR is associated with an increased risk and poor prognosis [1]. Potentially, the assessment of the hemodynamic significance of varying degrees of insufficiency in a particular patient and the study of its influence on the remodeling of the heart can help in the choice of treatment approach. At the same time, heart chambers or hemodynamic characteristics, which change due to the direct impact of IMR, can be considered effectors of regurgitation [2]. One of the main effectors of chronic IMR is the left atrium (LA). It is known that an increase in the volume of LA is a powerful predictor of mortality, but it is unclear how its

mechanical function changes, which depends on the overload with a regurgitating volume and thus may become an important component in assessing the effects of regurgitation [3]. In study by Wang Y, Zhang Y, Zhu Q.et al. it has been shown that strain indicators and strain rate of LA are earlier and more sensitive indicators of volume overload than geometric changes in the atria [4]. There are number of studies regarding the changing strain in patients with arterial hypertension, CHD, and atrial fibrillation, while the contribution of mechanical LA function to the process of global heart remodeling in patients with IMR has not been practically evaluated. In the literature, there are few data on the mechanics of LA in patients with MR during the reservoir and systolic phase of the LA [5]. Features of the strain indicators in the other phases of the atrium (absorption phase and conduit period) have not been evaluated. The features of the functional volumetric and mechanical parameters of the LA depending on the severity of MR in all phases of the LA activity are not yet described. We assume that atrial strain and strain rate may be associated with the severity of IMR. The aim of the study is to evaluate the mechanical function of the LA in patients with IMR using the vector analysis of the movement rate of the endocardium.

Materials and methods

The study included 107 patients aged (56 ± 7.5) years old, of which 96 (89,7%) are men – hospitalized with coronary artery disease at our clinic in 2016–2020. The trial was conducted at 1 centers with a coordinating center.The Ethics Committee of the Scientific Center for Surgery approved this study with registration number 18 / 12.08. 2016 of the year and all patients provided written informed consent. The investigators vouch for the accuracy and completeness of the data and for the fidelity of this report to the trial protocol, which is available with the full text of this article .

The scientific study is prospective and cohort non–randomized study. Inclusion criteria: echocardiography showing I – III degree of MR, the presence of coronary artery disease showed by angiography requiring surgical revascularization, sinus rhythm with the heart rate ranging from 60 to 89 per minute, superior echocardiography visualization of LA endocardium. Exclusion criteria: Inclusion criteria: echocardiographic (EchoCG) CGI criteria I – III, the presence of coronary artery lesions during selective angiography meeting the criteria for surgical revascularization, sinus rhythm and normysystole (heart rate from 60 to 89 per minute) during the study, excellent EchoCG visualization endocardium LP.

The comparison group consisted of 20 healthy volunteers, of which men – 10 (50%), aged between 38 to 65 (52.6 ± 13,4) years old.

The study group included 12 (11.2%) patients with functional class II angina pectoris, 69 (64.5%) patients with functional class III angina pectoris and 26 (24.3%) patients with functional class IV angina pectoris. The time from the onset of symptoms of IHD was (4.5 ± 3.3) years. Patients who underwent a Q–wave myocardial infarction – 68 (63.6%), anterior with a Q–wave – 21 (19.6%), repeated myocardial infarction – 18 (16.8%). Symptoms of heart failure of II functional class were registered in 12 (11.2%) patients, III functional class in 64 (59.8%) patients and IV functional class in in 31 (29.0%) patients. 21 patients (19.6%) had concomitant diabetes mellitus type 2, and arterial hypertension was detected in 60 (56%) patients.

Patients received conservative therapy that complies with current guidelines for treatment of IHD such as acetylsalicylic acid , statins, beta–blockers, angiotensin–converting enzyme inhibitors [6]. All patients underwent a complex of clinical, laboratory and instrumental examinations (ECG, general and biochemical blood tests, coagulation parameters, chest X–ray, 24–hour ECG monitoring, echocardiography, coronary angiography. All the patients underwent echocardiography examination using Accuson S2000 equipped with a 4V1c probe.

The severity of the IMR was assessed by several quantitative parameters, including the measurement of the width of the proximal regurgitation jet (vena contracta, VC, average 0.52 ± 0.21 cm (p =0.01) for the group), the index of the area of the regurgitation flow (percentage of the jet relative to the area of the LA, the average MR value is 28.7 ± 11.5%, p =0.03) [6].The mean end–diastolic volume (EDV) in the study group was 116.3 ± 26.2 ml, the LV ejection fraction (EF) – 43.0 ± 11.2% (p=0.03), the maximum volume of LA – 78.5 ± 26.5 ml(p =0.02), the average pressure in the pulmonary artery – 26.5 ± 10.2 mmHg. All the patients in comparison group had no MR as shown in echocardiography and all the echocardiographic data corresponded to the norm [7]. For echocardiographic examination of the LA following indicators were evaluated characterizing the geometry (volumes), the function (volume change), and the mechanics of the LA (longitudinal deformation and strain rate). To study the function of the LA, the fraction of passive emptying as a characteristic of the conductor function, the fraction of active emptying (as a characteristic of the pumping function), and also the expansion index of the LA as an indicator of the reservoir function were evaluated [8]. Vector analysis of the longitudinal strain (strain, S, %) and strain rate (SR, s – 1) of the LA was carried out on the basis of a dynamic assessment of a two–dimensional echocardiographic image using the patented Speckle Tracking Syngo VVI technology .

SR and S were studied during the four phases of the LA activity: 1) the reservoir phase or the accumulation period, characterizes the flow of blood from the pulmonary veins during LV systole, when the mitral cusps are still closed; data acquisition was performed from the opening of the aortic valve cusps to the opening of the cusps of the mitral valve synchronously with the ECG: from the beginning of the ST segment to the end of the T wave; 2) conduit phase or percolation period associated with the flow of blood from the LA to the LV during its early diastole, the values were recorded from the opening of mitral valves until the end of the diastasis, synchronously with the ECG: from the end of the T wave to the beginning of the P wave; 3) the contractile phase or the period of atrial systole, displays the active flow of blood from the LA to the late LV diastole, measurements were performed from the begin-

ning of the P wave to the R wave on the ECG; 4) the absorption phase reflects the flow of blood from the pulmonary veins and the filling of the LA in the early LV systole, estimated from the closing of mitral cusps to the opening of the aortic valve cusps, which corresponds to the period from the peak of the R wave to the end of the S wave on the ECG [9].

Statistical analysis of the data was carried out using Statistica 8.0. Correlation analysis was carried out..For the description of quantitative data, the values of mean M and standard deviation SD were used. The evaluation of the statistical significance of differences p between the groups was carried out using parametric criteria with a normal distribution of the trait — the two–sample Student's t–test for comparisons of means ($\bar{x} \pm SD$).

Results

Maximum (78.5 ± 26.5 ml), minimum (53.4 ± 22.2 ml) and P–volumes of the left atrium (66.3 ± 24.6 ml) significantly differed in the patients of the study group and in the comparison group (47.6 ± 10.2 ml, 31.4 ± 8 ml, 38.8 ± 8.1 ml, respectively). Only a moderate direct correlation was found between the volumes of the LA and the MR area index of the flux (Rs = 0.46 for the MR and the maximum volume of the LA, Rs = 0.5 for the minimum, Rs = 0.45 for the P–volume of the LA). The fraction of passive emptying of the LA in the comparison group was significantly higher than in patients with MR, which indicates a decrease in atrial conduction function in patients with MR (26.5 ± 10.3% versus 15.3 ± 8.2%). A moderate inverse correlation was found between the index of the area of the flow of the MR and the fraction of passive emptying of the LA (Rs = –0.55). The larger id MR, the smaller the volume of fluid flowing through the LA into the LV during the conduit phase of the atria, thereby reducing the contribution of the atrium to the LV stroke volume, therefore, to the LV systolic function. A moderate direct correlation was found between the fraction of passive emptying and LV EF (Rs = 0.46), which indicates a moderate association between LV and LV dysfunction.

The fraction of passive emptying which reflects pumping function of LA was significantly reduced in patients with MR compared with the control group (22.4 ± 9.9% versus 28.1 ± 7.3%). There was a mild inverse correlation between the fraction of active emptying of the LA and MR (Rs = –0.27) The LA expansion index characterizing the atrial reservoir function was significantly higher in the comparison group (patients with MR 0.8 ± 0.5 versus 2.47 ± 0.8 in the comparison group. There was a strong inverse correlation between the LA expansion index and the index of the area of the flow of the MR (Rs = –0.76) which confirms the deterioration of the atrial reservoir function. When analyzing differences in the functional parameters of the LA depending on the degree of MR we found the absence of a significant difference in the fraction of passive emptying of LA between patients with moderate and severe MR (with second degree MR 13.9 ±8%, with third degree MR 14.8 ±7.2%).

However, when indexing the obtained data to the corresponding volume of the LA, significant differences were found (S in the group with MR –2.8 ± 0.7% / 10 ml of the maximum volume of the LA, in the comparison group – 7.5 ± 1.2% / 10 ml of the maximum volume of LA , which confirms the hemodynamic significance of chronic overload with regurgitating volume of blood of LA. Longitudinal systolic deformation of LA was significantly reduced in the contractile phase (in patients with MR –3.6 ± 2.3% versus –12.4 ± 1.8% in the comparison group) and in the absorption phase (in patients with MP –1.2 ± 0.3% versus –0.44 ± 0.7% in the comparison group, p <0.05). In the conduit phase, the deformation was minimal both in patients with MR and in the comparison group, but paradoxically larger values were recorded in patients with MR than normal (–0.37 ± 0.2 and –0.1 ± 0.17%, respectively). A pronounced direct correlation of S in the systolic phase of the LA and MR (RS = 0.88), moderate S in the conduit phase and MR (RS = 0.5) and inverse correlation S in the phase of absorption and MR (RS = –0.58), S in the reservoir phase and MP (RS = –0.5).

We analyzed indicators S of LA depending on MR.

The maximum differences were found in individuals without MR and in patients with minor MR during the systole of LA (–12.4 ± 1.8% vs. –6.5 ± 2.2%, p <0.05, respectively) and during the absorption phase (–0.44 ± 0.7% vs. –1.1 ± 0.07%, p <0.05, respectively), as well as between patients with mild and moderate MR (S during the period of LA systole in patients with MR Grade I –12.3 ± 2.8% versus – 6,5± 1,4 % with MR of Grade II; S during the absorption phase with MP of the I degree – 1.8 ± 0.07 % versus –1.4 ± 0.07). Similarly to the indicators of SR between patients with moderate and severe MR, no differences in S values were found in all phases

In contrast to previous studies of mechanical function of LA, which evaluated only the peak positive longitudinal S and SR (as indicators of the accumulation period) and the peak negative S and SR (as indicators of the systolic phase of the LA), we attempt to give a comprehensive assessment of the atrial activity along with the contribution of the conduit and suction phase. Thus, the deformation values obtained during the period of blood flow from the LA to the LV in the normal state more reflect LV function than the LA function. But, as demonstrated in our study, the presence of chronic MR significantly changes the deformation rate of LA in the conduit period proportionally to the severity of regurgitation (which is confirmed by a direct correlation of MR and SR during this phase). Deformation in patients with minor MR in the conduit phase are minimal, and in patients with moderate and severe MR, they are close to zero during the entire phase. Consequently, the LA in the conduit period in patients with moderate and severe MR in terms of deformity functions as a "passport" with minimal S and SR values even during the early filling of the left ventricle. With inhibition of the deformity in the systolic phase of the LA, it becomes clear that the mechanical contribution to the filling of the LV is significantly reduced, despite the increase in the maximum volume of the LA. Perhaps these changes are related to the processes of structural remodeling of the atrium and loss of elastic properties due to chronic overload with the regurgitated blood volume. The

changes of the deformation we detected in the absorption phase were multidirectional in the control group, patients with minor regurgitation and patients with III – IV degree of MR. Deformation in this phase is close to zero, which is normal (in the control group S –0.44 ± 0.7). The presence of more negative results of deformation in patients with MR (–1.3 ± 0.07%) during this period remains unclear. In patients with III and IV degree of MR, the deformation values were even lower than in patients with mild MR. It is possible that due to atrial remodeling caused by MR, since the deformation was recorded synchronously with the ECG (from the R–wave to S), from the view of electrical processes, this was already the phase of LA absorption, and from the point of view of mechanics, the end of the LA systole period. It is because of the complexity of differentiation of the onset of the phases most researchers prefer to ignore this phase and not to study its features.

Normally, during the phase of the LA reservoir (towards the end of the LV systole), the maximum (among all LA phases) positive deformity is recorded, which is accompanied by the greatest increase in atrial volume. The reservoir period depends on the preload conditions and is fundamentally volume dependent. This means that the deviation of the mechanical characteristics from the normal range is related to the additional volume appearing in the atrium during this period (i.e., directly from the MR). The data obtained by us can be explained by taking into account the mechanical and functional changes along with the all phases of the LA. With a mild degree of MR, there was an increase in the active volume of the LA, due to which, in patients with stage I of MR, the fraction of active emptying remained within normal limits and compensated for the mechanical synergy. But with a moderate and pronounced degree of IMI, indicators characterizing contractility were decreased. Similarly to the classical Frank – Starling curve after a certain "threshold" volume of chambers further growth of contractility does not occur: it begins to decrease. In our study, this "threshold" was not the atrial volume, but the LA expansion index, which functionally characterizes the reservoir phase. A correlation was found between the expansion index and the fraction of active emptying of the LA (Rs = 0.70), the expansion index and the deformation rate of the LA in the reservoir phase (Rs = 0.63).

In this study, we demonstrated the importance of analyzing mechanical data (SR and S in patients with IMR) for complex assessment of the function of LA, along with traditional geometric parameters. Atrial activity can be interpreted not only from the standpoint of changes in atrial size and volume, but also on the basis of the evaluation of the mechanical properties of LA. Particularly noteworthy is the identification of a significant difference in SR inhibition between patients with mild and moderate MR and uncertain differences in SR indices in patients with moderate and severe MR. The results obtained probably indicate comparable ultrastructural changes in the atria that occur with chronic volume overload of MR from grade II and higher. Further detailed study of the dynamics of the mechanical function of the LA in patients with MR may be a promising and useful tool in assessing its hemodynamic significance and in the choice of surgical approach for additional intervention on mitral valve with IMR.

Discussion

The novel metric of ECG PL identifies patients with fewer (≤3) or greater numbers of stable rotors/focal sources for AF, validated by intracardiac FIRM mapping, and localized them to right or left atria. These data open the possibility of using 12–lead ECG analyses to classify AF mechanistically and plan procedures for right– or left–sided FIRM ablation. At the same time, the obtained data allow the normal reference ranges for the three components of left atrial function are demonstrated. The between–study heterogeneity is explained partly by heart rate, body surface area, and sample size.

The qualitative assessment of LA deformation and its practical value has been the subject of discussion in the last decade. Pathan F, et al showed that LA deformation is reciprocally associated with LV deformation, in other words, all mechanical processes in the atrium are only a mirror reflection of LV deformation and are more dependent on movement of the annular plane of LV systolic and diastolic functions [10].

However, further studies showed significant limitations of these data, demonstrating the significance of atrial contribution (systolic negative deformation) in the formation of an adequate preload of the LV and the contribution of reservoir phase (diastolic positive deformation of the LA) in the formation of the LV stroke volume [11]. In addition, the conduit function of LA depends on afterload, largely determined by the pressure in the receiving chamber which is LV, which increases as the diastolic stiffness and systolic dysfunction of the LV increases [12]. Of course, the conduit period is difficult to evaluate, since it is biphasic: during the beginning of early filling of the LV, atrial deformity is minimal, but the deformation rate is highest, however in the second period, we witness the plateau, when both the deformation and the deformation rate are close to or equal to 0. As well as other authors was good interobserver agreement of LA strain values between novice and expert . SR values also demonstrated good interobserver agreement . Of all parameters, SR–LAa had the best interobserver and intraobserver agreement . Global LA strain and SR values were highly reproducible by novice strain reader using multi–vendor analysis software. Interobserver reproducibility between novice and experts were good and acceptable within limits of agreement. Lau DH, et al., showed that a decrease in S and SR is an independent predictor of ultrastructure changes in LA, in particular interstitial fibrosis [13]. Consequently, a decrease in deformity into the conduit phase of LA may be considered an effector of hemodynamic significance of MR. Several authors indicated the reduced SR and S in the atrial systole are associated with the severity of regurgitation [14].

Conclusion

1. Echocardiographic parameters of the mechanical function of the left atrium change in accordance with the severity of the ischemic mitral regurgitation .

2. Indicators of strain rate and strain of the atrium mainly depend on the degree of mitral regurgitation, while conventional indicators of geometry and function of left atrium are less dependent on the magnitude of regurgitation.

3. In proportion to the severity, ischemic mitral regurgitation is associated with mechanical remodeling of the atrium, concomitant with changes in strain and strain rate values in left atrium activity.

4. In terms of the degree of changes in strain and strain rate against the background of moderate and pronounced ischemic mitral regurgitation, there are no special differences; this confirms the significance of even a moderate degree of regurgitation for the processes of mechanical left atrium remodeling.

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