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Violation of ventricular interactions in patients with severe aortic regurgitation

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Abstract

Aim

The aim was to study the effect of severe chronic aortic regurgitation (AR) on right ventricular (RV) diastolic function by using transthoracic echocardiography.

Materials and methods

This study examined 57 patients with AR. All patients who had lesions of other heart valves, coronary arteries, left ventricular ejection fraction (LVEF) <55%, and an increase in pulmonary artery pressure >25 mmHg were excluded from the analysis of the results. The remaining 25 (44%) patients were enrolled in a study group. All patients were male with a mean age 35±5 years. Patients had New York Heart Association (NYHA) class II-III chronic heart failure. The control group consisted of 10 healthy volunteers (mean age 34±6 years). All patients underwent echocardiography. RV diastolic function was evaluated during sinus rhythm using PW-Doppler echocardiography. The

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parameters of transtricuspid flow were calculated, namely early filling velocity (E) of the RV; right atrial systolic velocity (A); their ratio (E/A); acceleration, deceleration, and duration times of E; duration time of A, velocity–time integrals of E and A (VTI E and VTI A); RV isovolumic relaxation time (IVRT). Statistical data processing was performed using STATISTICA 6.0 software. The value of P<0.05 was considered statistically significant.

Results

There was no statistically significant difference identified between patients and controls with regard to age, height, body weight and heart rate. Systolic and diastolic blood pressure (BP), left ventricular mass index (LVMI), left ventricular end-diastolic (LVED) dimension, left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic (LVES) dimension, left ventricular end-systolic volume (LVESV), and left atrial size were significantly greater in patients with AR than in controls. There was no significant difference in patients with AR and controls regarding echocardiographic parameters characterising the right chambers of the heart: RV fractional area change, RV anterior wall thickness and the area of the right atrium. Significant difference between controls and patients with AR was observed in the right ventricular end-diastolic (RVED) dimension. Transtricuspid flow parameters in patients with AR, namely E/A of RV, RV IVRT, and VTI, were significantly different from those in controls. A high correlation was observed between the degree of AR and the occurrence of RV diastolic dysfunction (r=0.71).

Conclusion

LV volume overload violates interventricular interaction and negatively affects RV diastolic function. It is necessary to analyse in detail transtricuspid flow in patients with severe chronic AR to assess the condition of their RV.

Keywords

Right ventricle, aortic regurgitation, interventricular interaction, structure of the myocardium of the heart, right ventricular diastolic function

Introduction

The role of the RV to ensure adequate performance of the heart has been a subject of scientific and clinical interest >50 years. The results of experimental studies in 1943 and 1963 showed that destruction of the RV free wall or its complete replacement by a synthetic patch do not significantly affect the pumping function of the heart and systemic hemodynamic parameters [1,2]. In the literature until the mid 1980s of the last century, there were not many discussions about the functional significance of the RV because it was seen as a passive conduit or vessel via which blood travels from the venous system through the pulmonary circulation in the arterial bed of the systemic circulation.

In recent years, a view of the RV as a simple "conductor" of blood from a large to a small circle has been completely revised. In clinical practice, it has become extremely important to identify the prognostic value of the RV functional status compared to the LV, both at conservative and surgical treatments of various diseases of the heart, as evidenced by the high incidence of RV dysfunction (up to 37%) in the structure of hospital mortality from acute heart failure [3-5].

It is known that the ventricles are in close interaction. This implies three mechanisms: the unified volume of blood pumped, the unified pericardium, and, finally, the shared wall – septum, which carries out the mechanical interaction between the ventricles [6,7].

Studying muscle fibre orientation of the ventricles of the heart began almost 400 years ago when William Harvey (1628) discovered the circulation of blood. Studies by the Spanish scientist Torrent-Guasp F., et al. changed an understanding of the anatomical structure of the ventricular myocardium [8]. In these studies, it was shown that the ventricular myocardium is rolled into a spiral and during dissection of the heart in a certain sequence; it unfolds into a single muscle strip, the edges of which are the trunk of the pulmonary artery and the aorta (Figure 1).

In recent years, many scientists from leading cardiology clinics have successfully proved the "theory of a spiral single layer structure of the myocardium". In the *Russian Research Centre of Surgery named after Academician B.V. Petrovsky,* the study has been conducted which also proved the legitimacy of Torrent-Guasp's claims.

We studied a direction of the muscle fibres of the LV and RV myocardium by the Torrent-Guasp method (Figure 2).

When dissecting the myocardium through the passage of the left anterior descending artery, the RV free

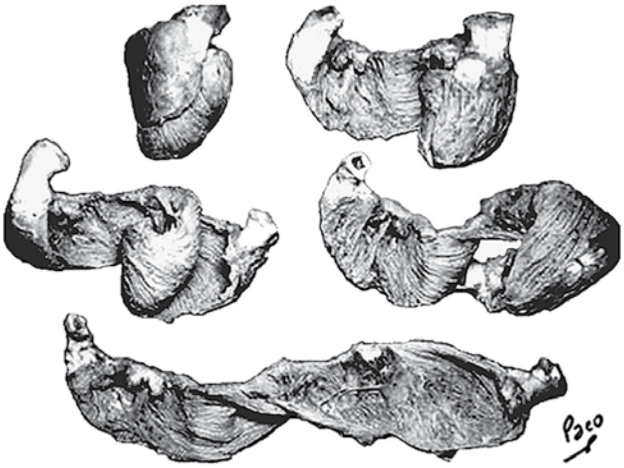

Figure 1. Ventricular myocardium rolled into a spiral (from La Mecanica Ventricular. Rev Lat Cardiol. 2001;22(2):50)

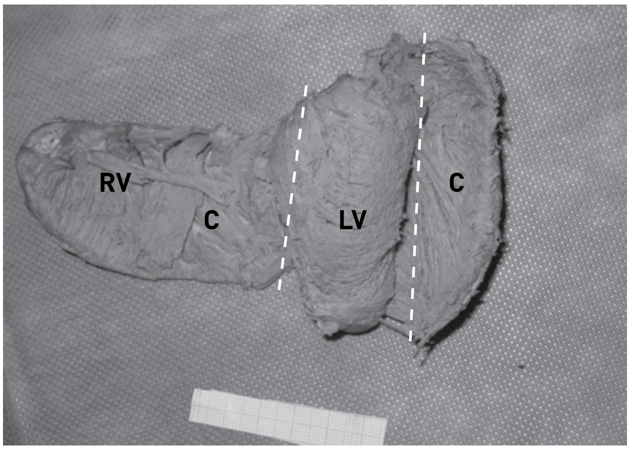

Figure 2. Dissection image of a lamb's ventricles

wall gets separated, and the bulk of the myocardium, including the interventricular septum, belongs to the LV. The great muscular layer in Figure 2, indicated by the letter "C", departs from the RV, covers the LV and becomes woven again into the RV myocardium. As a result, the heart unfolds on the RV and LV, taking a form of a muscle strip.

The idea of dividing the myocardium of the heart on LV and RV parts is very conditional. At least in functional terms, they should be considered as a whole [4].

The muscular frame of the walls of both ventricles is formed by longitudinal, transverse, and circular fibres of the superficial and deep muscle groups, which cover the RV and LV cavities with 4 layers, similar to the layers of fabric in a Turkish turban [7,9]. This structure explains the occurrence of simultaneous contraction of the entire myocardium and the close cooperation of all anatomical structures of the heart.

Close anatomical relations of muscle fibres cause changes in the RV during the remodelling of the LV of the heart [10-12].

Despite the extensive experience of surgical treatment of acquired valve disease [4-5], the problem of comprehensive use of simple and non-invasive techniques in determining the functional state of the RV in patients with abnormal heart valves is not currently described. In this context, the problem of an echocardiographic assessment of the RV at present becomes very important.

Diastolic myocardial dysfunction often plays a key role in the clinical manifestations of cardiovascular disease. It can be an early sign of pathology, and precedes clinical manifestations of systolic dysfunction. RV diastolic function attracts increasing attention of researchers and clinicians [13-17].

Taking into account a new understanding of the anatomical structure of the myocardium, a study was conducted, the purpose of which was to study the effect of chronic severe AR on the RV diastolic function, using transthoracic echocardiography.

Materials and methods

To assess the RV diastolic function, 57 patients with severe chronic AR were examined. The data of patients with combined defects of other heart valves, coronary artery lesions, LVEF <55%, and with an increase in pulmonary artery pressure >25 mmHg were excluded from the analysis of the results. The remaining 25 (44%) patients were enrolled in the study. All patients were male. The mean age of the patients was 35±5 years. 10 patients showed signs of LV hypertrophy. The main complaint of patients was dyspnoea, corresponding to NYHA class II-III.

All patients included in the study had severe AR according to echocardiography and angiographic criteria.

The control group consisted of 10 healthy volunteers with the mean age of 34±6 years.

All patients underwent comprehensive two-dimensional echocardiography using an ultrasound scanner (GE Vivid 7) equipped with a 2.5–4.7 MHz multifrequency probe allowing simultaneous recording of one standard lead electrocardiogram. All echocardiographic measurements were performed according to the recommendations of the American Society of Echocardiography [18].

Assessment of RV diastolic function was performed in sinus rhythm in the mode of pulsed Doppler echocardiography.

The following parameters of transtricuspid flow were calculated: maximum early filling velocity of the RV (VmaxE), right atrial peak systolic velocity (VmaxA), their relationship (VE/VA), E wave acceleration time (AccT E), E wave deceleration time (DecT E), E wave duration time (DT E), A wave duration time (DT A), integral of the linear peak velocity of E and A (VTI E and VTI A, respectively), RV isovolumic relaxation time (IVRT), which was defined as a period between closing of the pulmonary valve and opening of the tricuspid valve. Diastolic indices were measured in 3 consecutive complexes; their values were averaged in order to minimize the effect of the act of breathing on the RV diastolic filling.

Statistical data processing was performed using STATISTICA 6.0 software. When analyzing, the mean (M) ± standard deviation (SD) were calculated. The significance of differences was assessed by the Student's t-test. The value of $P<0.05$ was considered statistically significant.

Results and discussion

There was no statistically significant difference between patients and controls with regard to age, height, body weight, and heart rate. Systolic and diastolic BP, LVMI, LVED dimension, LVEDV, LVES dimension, LVESV, and left atrial size were significantly greater in patients with AR than in controls. There was no significant difference between patients with AR and controls regarding echocardiographic parameters characterizing the right chambers of the heart: RV fractional area change, RV anterior wall thickness and the area of the right atrium. RV systolic pressure was estimated according to maximal tricuspid regurgitation velocity, and was <30 mmHg in all patients included in the study. Significant difference between patients with AR and controls was observed in the RVED dimension (Table 1).

Patients with AR had lower peak E-wave velocity than peak A-wave velocity, and the E/A ratio was lower as compared with controls (Figure 3).

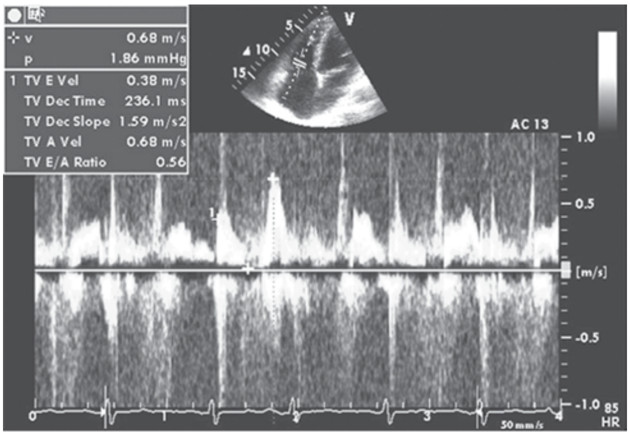

Figure 3. Diastolic transtricuspid blood flow

Table 1. **Comparison of clinical and echocardiographic parameters in patients with AR and controls (M±SD)**

Parameters	Controls (n=10)	Patients with AR (n=25)	P
Age, years	34±6	35±5	0.610
Height, m	1.72±0.22	170±0.08	0.866
Weight, kg	74.2±8.7	73.7±7.7	0.773
Heart rate, beats/min	69±6	74±5	0.955
Systolic BP, mmHg	131±6	152±9	<0.01
Diastolic BP, mmHg	75±4	54±4	<0.01
LVMI, g/m^2	98±13	188±43	<0.001
LVED dimension, cm	5.1±0.3	6.8±0.5	<0.001
LVEDV, mL	105±1.1	183±35	<0.001
LVES dimension, cm	3.1±0.2	3.9±0.5	<0.001
LVESV, ml	45±3	85±14	<0.001
LV, cm	3.5±0.1	4.5±0.1	<0.001
RVED dimension, cm	1.9±0.2	2.9±0.1	<0.001
RV anterior wall thickness, cm	0.4±0.02	0.5±0.01	0.43
RV fractional area change, %	49±6	48±7	0.74
Area of the right atrium, cm^2	12±0.5	14±0.4	0.55

The transtricuspid flow parameters, such as ratio of RV filling velocities (E/A), RV IVRT, and VTI, in patients with AR were statistically significantly different from those in controls, and were lower (Table 2).

Table 2. **Comparison of the echocardiographic parameters of transtricuspid flow in patients with AR and controls (M±SD)**

Parameters	Controls (n=10)	Patients with AR (n=25)	P
VE/VA	1.33±0.07	0.98±0.09	<0.01
RV IVRT, msec	70.75±2.70	76.86±3.7	<0.01
VTI, cm	21.20±0.72	20.2±1.01	0.65

The RV creates a sucking effect during early diastole, which ensures free flow of blood into the cavity. During late diastole, right atrial contraction contributes to additional RV filling. Early manifestation of RV myocardial dysfunction is a disorder of its diastolic compliance.

A high correlation (r=0.71) between the degree of AR and violation of RV diastolic function was noted (Figure 4).

These results demonstrate the relationship between the LV volume overload, violation of interventricular communication and emergence of RV diastolic dysfunction in patients with AR.

This study allowed us to estimate the influence of LV volume overload and violation of interventricular communication on RV diastolic function. These data indicate impairment and degradation in relaxation of the RV which is filled with redistributed transtricuspid blood flow during early and last diastoles. The key

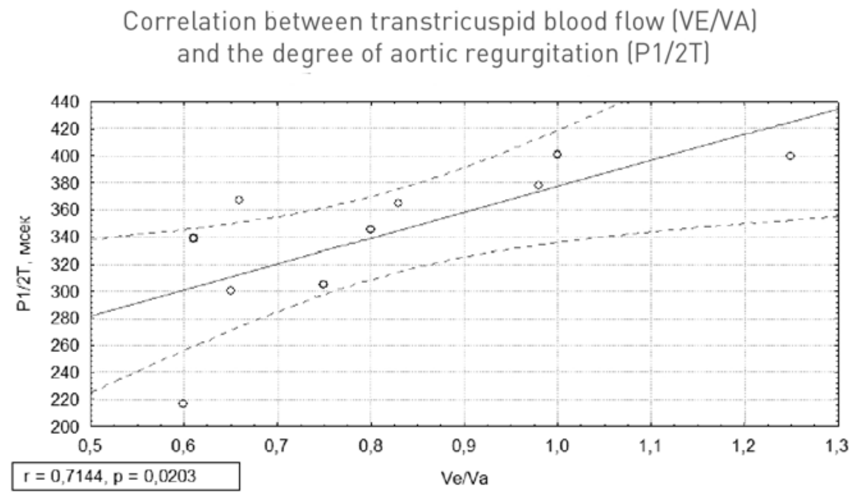

Figure 4. Dependence of the parameters of RV diastolic function and degree of AR

mechanism of this action is a violation of interventricular communication as a result of the LV dilatation and diastolic changes of the RV side of the interventricular septum. Thus, in patients with severe AR and chronic LV volume overload, a violation of RV diastolic function occurs.

Conclusion

Transthoracic echocardiography allows evaluation of intracardiac blood flow and diastolic function of the RV and LV [19].

Comprehensive echocardiographic study in patients with severe chronic AR enables diagnosis of a violation of the interventricular communication and the occurrence of RV diastolic dysfunction.

The analysis of echocardiographic indices indicates an abnormality in transtricuspid blood flow, deterioration in myocardial relaxation, and occurrence of RV diastolic dysfunction in patients with severe chronic AR.

RV diastolic dysfunction plays an important role in progression of chronic heart failure [17,20]. Determination of the RV functional state is an important criterion for assessing the severity of the clinical course and prognosis of surgical treatment in these patients.

Conflict of interest: None declared

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