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ORIGINAL RESEARCH ARTICLE

Evaluation of Left Ventricular Function by Conventional Echocardiography and Tissue Doppler Imaging in Patients with Acute and Chronic Mitral Regurgitation

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Left ventricular function is affected differently in acute and chronic mitral regurgitation (MR). Twenty-six patients (12 men and 14 women, average age: 55 ± 20 years) with acute severe MR caused by flail leaflet and 30 patients with chronic severe MR of organic origin (14 men and 16 women, average age: 56 ± 14 years) were included in the study. All of the patients were evaluated in detail by conventional echocardiography and tissue Doppler imaging (TDI). Among conventional echocardiographic parameters, left ventricle ejection fraction (%) was found higher in acute MR (71 ± 5/59 ± 12, $p = 0.001$) whereas left ventricle end-systolic volume, left ventricle end-diastolic volume, left ventricle end-systolic diameter, left ventricle end-diastolic diameter, left atrium dimension, and left atrial area were significantly higher in chronic MR. Among TDI parameters, peak systolic wave velocities (11.4 ± 3.6/8.8 ± 2.5 cm/s, $p = 0.018$), peak early diastolic velocities (10.8 ± 4.5/9.3 ± 3.8 cm, $p = 0.03$), and contraction time (248 ± 56/219 ± 47 ms, $p = 0.04$) were found higher in acute MR, whereas precontraction time (119 ± 29/164 ± 48 ms, $p = 0.005$) and precontraction time to contraction time ratio (0.52 ± 0.23/0.78 ± 0.28, $p = 0.008$) were significantly higher in chronic MR. As evaluated by conventional echocardiography, the systolic function of chronic MR was also normal, although it was lower than that of acute MR. We also found that left ventricular systolic and diastolic

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functions by TDI were also relatively preserved in patients with acute MR when compared with those with chronic MR.

Introduction

Mitral regurgitation (MR) is a commonly progressive disease associated with significant morbidity and mortality [1—3]. The progression rate may be slow and insidious or abrupt as a result of a chordal rupture (CR) leading to flail leaflet [4]. In acute severe MR, a sudden volume overload is imposed on the left atrium (LV) and left ventricle (LV). The absence of compensatory eccentric hypertrophy, forward stroke volume, and cardiac output are reduced. At the same time, the unprepared LA and LV cannot accommodate the regurgitant volume, which causes large v waves in the LA and results in pulmonary congestion [5]. However, patients with chronic MR may not be hemodynamic compromised for many years [5]. Once the MR has become severe, there has been time for the development of eccentric cardiac hypertrophy [6,7]. At the same time, the increase in LV and left atrial size allows the accommodation of the regurgitant volume at a lower filling pressure, and the symptoms of pulmonary congestion abate. In this phase of compensated MR, the patient may be entirely asymptomatic. However, the prolonged burden of volume overload may eventually result in LV dysfunction. In this phase, contractile dysfunction impairs ejection and end-systolic volume increases. There may be further LV dilatation and increased LV filling pressure.

Echocardiography plays a pivotal role in the evaluation of MR. It is useful in diagnosing MR and in determining its severity and cause. In recent years, tissue Doppler imaging (TDI) has become a well-accepted, practical, safe and noninvasive method for the diagnosis of ventricular systolic and diastolic functions in a variety of clinical setting [8,9]. By using TDI, it is possible to detect the abnormalities in the contraction and relaxation functions of the myocardium, which cannot be detected by traditional echocardiographic methods [10]. The purpose of this study was to evaluate LV functions by conventional and TDI in patients with acute and chronic MR.

Methods

Twenty-six patients (12 men and 14 women, average age: 55 ± 20 years) with acute severe MR caused by flail leaflet and 30 patients with chronic severe MR of organic origin (14 men and 16 women, average age: 56 ± 14 years) were included in the study between June 2007 and January 2009. Changes in left ventricular function in acute and chronic MR were studied using conventional echocardiography and TDI.

Severe mitral regurgitation was diagnosed echocardiographically in the presence of dilated LA, and LV, abnormal/flail leaflet, large central jet (usually $> 10\ cm^2$ or $> 40\%$ of left atrial area), variable size wall-impinging jet swirling in left atrial and regurgitant volume ≥ 60 (ml/beat), regurgitant fraction ≥ 50 (%) or effective regurgitant orifice area $\geq 0.40\ cm^2$).

Acute MR patients were made up of those with chordal ruptures of various etiologies. Clinical diagnosis of acute MR was done by the increase in New York Heart Association (NYHA) functional class or the development of new symptoms in patients with flail mitral leaflets due to chordal rupture. The echocardiographic examinations of acute MR patients were done during the clinically acute phase. Chronic MR patients were selected from patients being followed at our institution for rheumatic heart disease or degenerative valvular disease.

Transesophageal echocardiography (TEE) was considered as the reference method in diagnosing flail mitral leaflet (FML) [11,12]. FML was defined as failure of leaflet coaptation, with systolic eversion of the flail segment into the LA [11—15]. All cases of FML were caused by CR.

The exclusion criteria were mitral stenosis, aortic stenosis, moderate to severe aortic regurgitation, previous valve repair or replacement, primary right heart disease, papillary muscle rupture, dilated cardiomyopathy, hypertrophic cardiomyopathy, congenital heart disease and ischemic heart disease, ischemic MR and prominent calcific mitral annulus, renal failure, hyperthyroidism, blood pressure $> 160/100$ mm Hg, and the presence of moderate or severe respiratory disease.

According to 2007 guidelines on the management of valvular heart disease by the European Society of Cardiology [16], 16 acute and 19 chronic MR patients were referred for surgery. During the operation, seven of acute MR patients had ruptured chordate tendineae of the A2 scallop while nine had a rupture in the P2 scallop. Moreover, three of these patients had degenerative changes, and two had sequelae of rheumatic fever. Eight of the chronic MR patients had degenerative changes, six had sequelae of rheumatic fever, and five had prolapsus.

Echocardiographic measurements

All participants underwent two-dimensional (2D) and Doppler echocardiographic evaluation by an experienced research echocardiographer using commercially available echocardiography machines equipped with a 2—4 MHz phased array transducer (Vivid 7 pro, GE, Horten, Norway). All participants also underwent TEE examination by using a TEE probe 6 T-OR (2.9—7 mhz) (Vivid 7 System, GE, Horten, Norway).

2D and pulsed-wave Doppler echocardiographic studies were performed in the left lateral decubitus position with the conventional views (parasternal long and short axis, and apical four-chamber views) [13]. Ventricular septum, left ventricular posterior free wall, LV end-diastolic diameter, LV end-systolic diameters, and LA dimension were

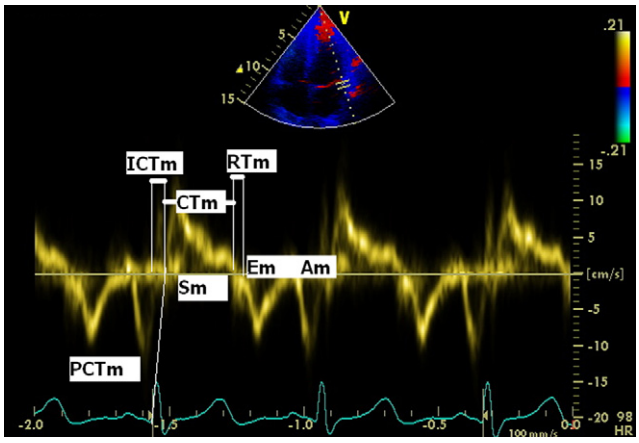

Fig. 1 Schema of the tissue Doppler imaging pattern of the left ventricular mitral annulus. Am = late diastolic velocity; CTm = myocardial contraction time; Em = early diastolic velocity; ICTm = isovolumic contraction time; PCTm = myocardial precontraction time; RTm = myocardial relaxation time; Sm = myocardial systolic velocity.

measured in the parasternal long-axis view [13]. The left atrial area (LAA) was measured from the apical four-chamber view [13]. The left atrium dimensions were used to calculate LA volume as an ellipse using the formula: LA volume $= \pi/6\ (D_1 \cdot D_2 \cdot D_3)$, where D_1 = parasternal short-axis M-mode LA dimension, D_2 = apical four-chamber view two-dimensional short LA axes, and D_3 = apical four-chamber view 2D long LA axes are measurements of 12. J.A. Murray, J.W. Kennedy and M.M. Figley, Quantitative angiocardiography. II. The normal left atrial volume in man. Circulation 37 (1968), pp. 800–804. View Record in Scopus Cited By in Scopus (31) at ventricular end-systole [17]. LA volume index was calculated as LA volume/body surface area.

The LV volume and the left ventricular ejection fraction (LVEF) were measured from the apical four-chamber view and two-chamber view using the modified Simpson method [13].

MF was graded both quantitatively and semi-quantitatively. The degree of MF was determined quantitatively by effective regurgitant orifice area (ERO), regurgitant fraction (RF), regurgitant volume (RV), and

Table 1 Clinical and echocardiographic parameters of the two groups.

	Acute MR ($n = 26$)	Chronic MR ($n = 30$)	p
Age (yr)	55 ± 20	56 ± 14	NS
Sex (m/f)	12/14	14/16	NS
Heart rate (bpm)	87 ± 21	93 ± 21	NS
Body surface area (m^2)	1.82 ± 0.12	1.81 ± 0.14	NS
Systolic BP (mm Hg)	119 ± 23	127 ± 28	NS
Diastolic BP (mm Hg)	73 ± 11	79 ± 17	NS
Diabetes mellitus (%)	1 (2.3%)	3 (10%)	NS
Atrial fibrillation (%)	1 (2.3%)	12 (36.6%)	0.019
NYHA class II (n)	4	7	NS
NYHA class III (n)	13	14	NS
NYHA class IV (n)	9	9	NS
LVEF (%)	71 ± 5	59 ± 6	0.001
LV end-diastolic volume (mL)	137 ± 35	184 ± 41	0.010
LV end-systolic volume (mL)	35 ± 11	52 ± 23	0.008
LV end-systolic dimension (cm)	2.9 ± 0.4	3.7 ± 0.7	0.001
LV end-diastolic dimension (cm)	5.0 ± 0.6	5.9 ± 0.6	0.011
Ventricular septum	1.05 ± 0.02	1.10 ± 0.11	NS
LV posterior wall	1.03 ± 0.04	1.10 ± 0.12	NS
LA volume index	50 ± 16	63 ± 18	0.003
Left atrium dimension (cm)	4.4 ± 0.8	5.3 ± 1.0	0.003
Left atrial area (cm^2)	27 ± 8	33 ± 10	0.048
Regurgitan jet area (cm^2)	12 ± 5	14 ± 4	NS
RJA/LAA ratio	0.45 ± 0.11	0.43 ± 0.11	NS
ERO area (cm^2)	0.51 ± 0.13	0.45 ± 0.11	NS
Regurgitant volume (mL)	68 ± 14	67 ± 18	NS
Regurgitant fraction (%)	0.58 ± 0.08	0.59 ± 0.10	NS
PA systolic pressure (mm Hg)	52 ± 11	51 ± 13	NS
Peak transmitral E velocity	1.5 ± 0.2	1.4 ± 0.2	NS
Mitral deceleration time (ms)	199 ± 30	201 ± 33	NS
E/Em ratio	16 ± 5	18 ± 5	NS
IVRT (ms)	79 ± 11	79 ± 22	NS

BP = blood pressure; E = peak early transmitral filling wave velocity; Em = early diastolic velocity of lateral mitral annulus; ERO = effective regurgitant orifice; LAA = left atrium area; LV = left ventricle; LVEF = left ventricle ejection fraction; IVRT = isovolumic relaxation time; MR = mitral regurgitation; NYHA = New York Heart Association functional classification; PA = pulmonary arterial; RJA = regurgitan jet area.

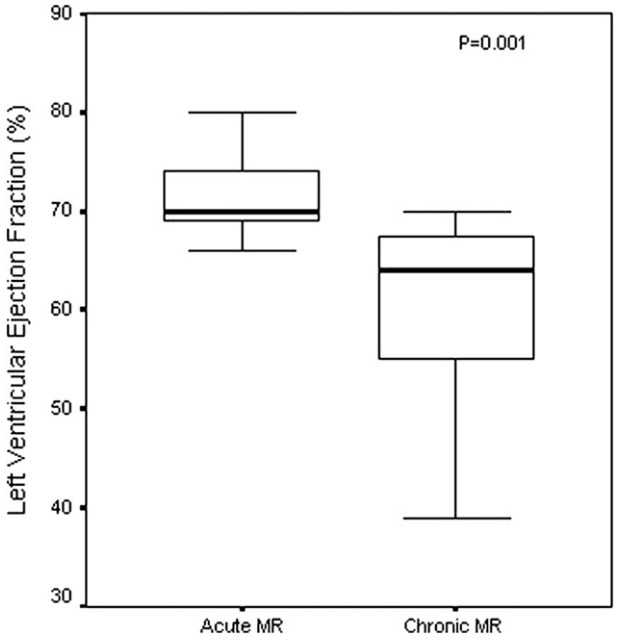

Fig. 2 The left ventricular ejection fraction of the two groups.

semiquantitatively by assessing the area of the regurgitant jet as a percentage of the left atrial area in the apical four-chamber view according to American Society of Echocardiography guidelines [14].

Pulmonary arterial systolic pressure (PASP) was estimated from the systolic trans-tricuspid pressure gradient ($\Delta P = 4\ V^2$, V = maximal tricuspid regurgitation m/s) + right atrium pressure (RAP). Right atrial pressure was estimated from the inferior vena cava (IVC) diameter adjacent to the right atrium in the subcostal view. This measurement involves examination of the IVC diameter during quiet respiration and forced inspiration. A diameter <2 centimeters with inspiratory collapse was used to identify a RAP of 5 mm Hg, dilatation with collapse identified RAP of 10 mm Hg, and dilatation without inspiratory collapse was used to identify a raised RAP of more than 15 mm Hg.

Left ventricular peak early diastolic transmitral flow velocity (E) and mitral deceleration time were also obtained from the apical four-chamber view by a pulsed-wave Doppler sample during diastole [18]. Isovolumetric relaxation time (IVRT) was measured with continuous wave Doppler echocardiography from the aortic valve closure to the onset of mitral inflow with the cursor positioned midway between left ventricular outflow and mitral inflow [19,20].

TDI was obtained with the sample volume placed at the lateral corner of the mitral annulus from the apical four-chamber view. The wall filter settings were adjusted to exclude high frequency signals and the gain was minimized. Three consecutive waves were obtained and their average taken for each parameter. The parameters taken were peak systolic velocity (Sm), a peak early diastolic velocity (Em), myocardial precontraction time (PCTm in milliseconds, from the onset of electrocardiogram QRS to the beginning of Sm), isovolumic contraction time [ICTm (the ECG reference was not taken in calculating the period from the end of Am to the beginning of Sm wave)], contraction time (CTm in milliseconds, from the beginning to the end of Sm), precontraction time to contraction time ratio (PCTm to CTm), and myocardial relaxation time (RT milliseconds, the time interval between the end of Sm and the onset of Em). This is shown in Fig. 1. The E/Em ratio, which is an important noninvasive marker of pulmonary capillary wedge pressure and LV filling pressure, was also calculated.

Statistical analysis

Statistical analysis was performed with SPSS for Windows, version 11.5 (SPSS Inc. Chicago, Illinois, USA). Data are presented as mean ± standard deviation. For continuous variables, an unpaired Student t test was used, and a chi-square test was used for categorical changes. A p value of <0.05 was considered statistically significant.

Results

Baseline clinical and echocardiographic variables are illustrated in Table 1. Distribution of sex, age, body mass index, heart rate, and blood pressure were similar in the two groups. The left ventricular ejection fraction (Fig. 2) was significantly higher in patients with acute MR when compared with those with chronic MR. LVSV, LVDV, LVDD, LVSD, LAA, and LA dimensions were significantly lower in patients with acute MR when compared with those with chronic MR. Atrial fibrillation was significantly lower in patients with acute MR when compared with those with chronic MR. There was no significant difference between the two groups in the degrees of MR, NYHA class, PASP, E/Em ratio, IVRT, and other echocardiographic parameters.

Table 2 Tissue Doppler indices of the study groups.

	Acute MR ($n = 26$)	Chronic MR ($n = 30$)	p
Peak systolic velocity (cm/s)	11.4 ± 3.6	8.8 ± 2.5	0.018
Peak early diastolic velocity (cm/s)	10.8 ± 4.5	9.3 ± 3.8	0.03
Contraction time (ms)	248 ± 56	219 ± 47	0.04
Precontraction time (ms)	119 ± 29	164 ± 48	0.005
Isovolumic contraction time (ms)	64 ± 18	64 ± 17	NS
PCT to CT ratio	0.52 ± 0.23	0.78 ± 0.28	0.008
Relaxation time (ms)	79 ± 22	83 ± 23	NS

CT = contraction time; MR = mitral regurgitation; PCT = precontraction time.

Tissue Doppler indices of the study groups are illustrated in Table 2. Peak Sm (Fig. 3), peak Em (Fig. 4), and CT were significantly higher in patients with acute MR when compared with those with chronic MR. Precontraction time and PCT-to-CT ratio were significantly lower in patients with acute MR when compared with those with chronic MR. The other TDI parameters were found to be similar in both groups.

Discussion

As evaluated by conventional echocardiography, we found that the systolic function of chronic MR was normal, although it was lower than that of acute MR. The LV systolic and diastolic functions by TDI were also relatively preserved in patients with acute MR when compared with those with chronic MR.

Acute MR is frequently due to flail mitral leaflet caused by CR. In general, it has a variety of clinical symptoms, including rest dyspnea, orthopnea, and possible signs of diminished forward flow. Although several studies have been carried out for the diagnosis, management, and clinical course of flail mitral valve, left ventricular functions have not been sufficiently evaluated in these patients. Therefore, we attempted to evaluate LV functions using both the traditional echocardiographic and TDI techniques.

Left ventricular pressure or volume overload is accompanied by myocardial remodeling in both acute and chronic MR [4,5,21]. In acute MR, the regurgitant volume that returns from the LA causes a sudden increase in LV end-diastolic volume. The LV compensates for this by means of the Frank-Starling mechanism: increased sarcomere length enhances LV contractility. Because acute MR reduces both late systolic ventricular pressure and radius, LV wall tension declines markedly (and proportionally to a greater extent than LV pressure), permitting a reciprocal increase

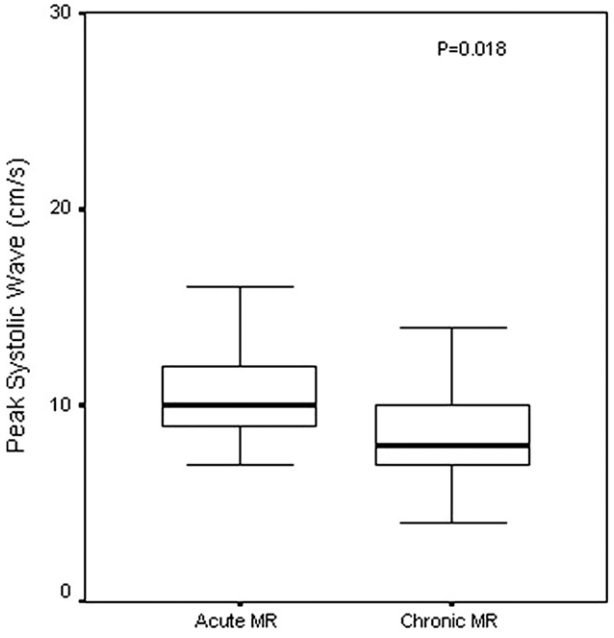

Fig. 3 Peak systolic wave velocities of the two groups.

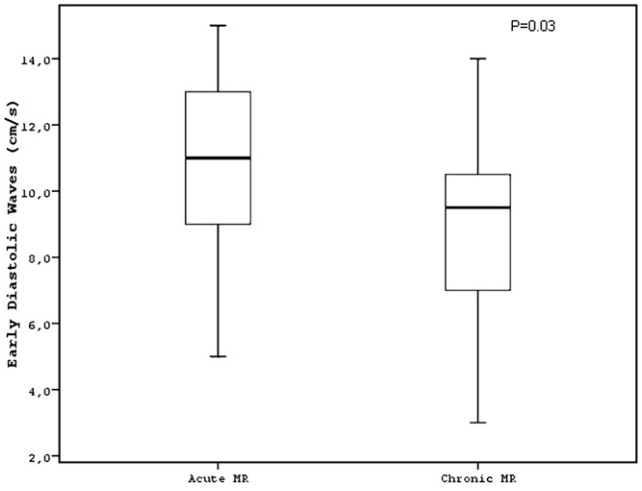

Fig. 4 Peak early diastolic wave velocities of the two groups.

in both the extent and the velocity of myocardial fiber shortening, which leads to a reduced end systolic volume and thereby more complete LV emptying occurs [5]. On the other hand, there is dilatation of the LV with eccentric hypertrophy in chronic MR. Wall stress is normalized with the development of hypertrophy. Left ventricular function is not hyperdynamic as in the acute state but is in the high-normal range. In chronic MR, diastolic wall stress increases and results in LV chamber enlargement. As the LV dilates, it becomes more spherical, and this change may reduce its efficiency. In particular, the longitudinal (base-apex) piston function may be compromised. In case of acute MR with FMV, hyper dynamic status such as increased inotropy and reduced afterload may account for the relatively better LV functions.

In our study, we found out that Sm values, Em, and CT were higher in the acute MR group, which showed better contractility, while PCTm and PCT-to-CT ratio (which is an indicator of the preservation of LVEF) were decreased [22]. High EF and Sm in acute MR may be due to compensatory response, because, when compared with chronic MR, LV remodeling parameters such as LVDV, LVSV, LVSD, and LVDD are nearly normal. Thus, the effect of remodeling was not considered as the primary effect.

Carabello BA [5] showed that in chronic decompensated MR, LVEF was lower compared with that in acute MR, whereas LVDV, LVSV, LVSD, LVDD, LAA and LA dimension values were higher than those in acute MR. In our study, the findings in conventional echocardiographic examinations were in accordance with these. In addition, Carabello BA [5] reported that LA pressures were similar in both acute and decompensated chronic MR patients.

In addition, the fact that there was no statistical difference between the NYHA functional class, PASP, E/Em of the groups was thought to be a result of the small sample size.

Conclusion

As evaluated by conventional echocardiography, the systolic function of chronic MR was normal, although it was

lower than that of acute MR. In addition, we found that the LV systolic and diastolic functions by TDI were also relatively preserved in patients with acute MR when compared with those with chronic MR.

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