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Research Article

The Assessment of Right Ventricular Longitudinal Strain in Patients with Mitral Stenosis

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ABSTRACT

Early detection of Right Ventricular (RV) failure is particularly important in managing patient with MS, due to its significant role in clinical symptoms and prognosis of MS. One of the new developed methods for quantifying RV function is Right Ventricular Longitudinal Strain (RVLS) analysis. This study aims to assess RV function in patients with mitral stenosis by strain analysis, and also to evaluate the correlation between echocardiographic findings and right ventricular dysfunction. Conventional echocardiography and two-dimensional RVLS were performed in 50 MS patients (mean age of 39 ± 8 years) and 35 age-matched healthy control subjects (mean age of 36 ± 10 years). Right ventricular longitudinal strain was calculated as the percentage of systolic shortening of the RV free wall from base to apex in the RV-focused four-chamber view. Patients in this study were patients with isolated severe MS, with Mitral Valve Area (MVA) 0.73 ± 0.16 cm^2 and mean Mitral Valve Gradient (MVG) 13.40 ± 3.74 mmHg. Compared with the control group 2D RVLS was lower in population with MS (-18.29 ± 6.75 vs. -31.31 ± 5.24). There was a moderate correlation between RVLS and Tricuspid Annular Plane Systolic Excursion (TAPSE). Additionally, there was a moderate correlation between RVLS and Tricuspid Regurgitation Velocity (TRV) max, Tricuspid Valve Gradient (TVG), and Pulmonary Acceleration Time (PAcT). There was poor correlation between RVLS and MVA but no correlation between RVLS and mean MVG. Our study demonstrated that patients with MS had lower RV function using 2D RV longitudinal strain. Impaired RV function in these patients is more likely due to the increase in RV afterload and pulmonary hypertension.

Keywords: Mitral stenosis; Right ventricular longitudinal strain; Right ventricular function; Speckle-tracking echocardiography; Tricuspid valve gradient

INTRODUCTION

Rheumatic heart disease remains a major health problem, particularly in developing countries where it causes significant cardiovascular morbidity and mortality in young people [1]. Mitral Stenosis (MS) is the predominant form of valve involvement in rheumatic disease which usually produces increase in the backflow pressure in the pulmonary vasculature which causes pulmonary venous hypertension [1,2].

Right Ventricular (RV) function plays an important role in development of clinical symptoms and prognosis in patients with MS. Right ventricular systolic dysfunction occurs early before clinical systemic congestion. For this reason, detecting RV failure earlier is of particular importance [2-4].

Echocardiographic assessment of RV function is challenging due to complex anatomy of RV, narrow acoustic window, and high load dependence [3-6]. Many indices have been developed for quantifying RV function, among which strain and strain rate is relatively new.

Tissue Doppler Imaging (TDI) has significant drawbacks, such as angle dependent, low spatial resolution and analysis in only one dimension. Speckle-Tracking Echocardiography (STE)-derived strain imaging is less confounded by overall heart motion [7]. It enables angle independence and Two-Dimensional (2D) assessment and it has been shown in many studies that 2D strain imaging is better than conventional Doppler and TDI in the determination

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of RV function [4].

Myocardial strain is a measure of tissue deformation, which is expressed as a percentage change, whereas, strain rate is the rate of such deformation [3,4,8]. Various studies have demonstrated the importance of 2D strain analysis in assessing RV function in different disorders. However, there are only a few studies, which assessed 2D RV strain in patients with isolated MS [3,4,9].

This study was designed to assess RV function in these subjects by longitudinal strain analysis and the correlation between echocardiographic findings and right ventricular dysfunction.

METHODS

The study population consisted of 50 patients with isolated MS and 35 healthy control subjects. Patients with significant mitral regurgitation, any significant aortic valve abnormality, moderate-to-severe valvular disease other than MS, impaired left ventricular systolic function (LV ejection fraction <50%), concomitant congenital heart disease, coronary heart disease, diabetes mellitus, and hypertension were excluded from the study.

Echocardiographic examinations were done using the General Electric Vivid E9 system (GE Vingmed Ultrasound AS, Horten, Norway) with a 3.5 MHz transducer. All data were analyzed in a workstation (EchoPAC PC; GE Vingmed Ultrasound AS). Mitral stenosis severity is evaluated based on the 2009 EAE/ASE Recommendations Echocardiographic of Assessment of Valve Stenosis for Clinical Practice [10].

Right Ventricular Longitudinal Strain (RVLS) was obtained and reported as the average of peak longitudinal strain of three RV free wall segments (basal, mid, and apical) obtained from the RV-focused four-chamber view. All images were obtained during breath hold and stored in cine-loop format from 3 to 5 consecutive beats. The frame rate for images was between 50 and 90 frames/s. After manually defining the endocardial border, the software system constituted an automatic epicardial tracing for each view. When the Regions of Interest (ROI) included the whole thickness of the RV, the process was initiated and the software system advanced the tracking frame-by-frame. If the automatically obtained tracking segments were adequate for analysis, the software system was allowed to read the data, whereas analytically inadequate tracking segments were either corrected manually or excluded from the analysis.

Study protocol was approved by local Ethics Committee of our institute and a written informed consent was obtained from each patient (Figure 1).

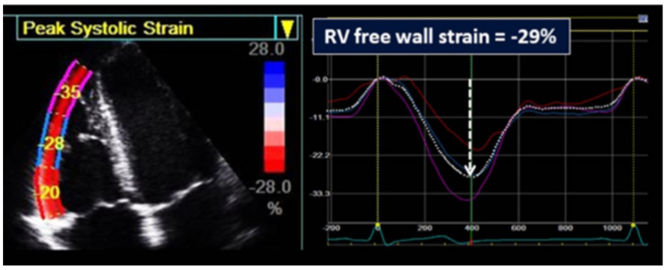

Figure 1: Measurement of RV free wall longitudinal strain by 2D STE whereby the three segments of the free wall are averaged.

Statistical analysis

Collected data were computerized and analyzed using Statistical Package for Social Science (SPSS) version 25. Quantitative variables were expressed as mean ± Standard Deviation (SD). Shapiro-Wilk test was used for testing for normality. Student's t-test was used to compare the normally distributed continuous variable between patients with MS and the healthy control group. Pearson correlation analysis was done to show the relationship between the variables in MS patients. Interobserver and intraobserver Intraclass Correlation Coefficients (ICCs) for quantitative measurement of RVLS were calculated in a 2-way mixed model with 95% Confidence Intervals (CIs). The agreement between interobserver and intraobserver reliability analyses was tested by the Bland–Altman method P values<0.05 were considered statistically significant.

RESULTS

The study subjects consisted of 50 patients with isolated severe MS (38 women and 12 men, mean age: 39 ± 8 years) and 35 age-matched healthy individuals (26 women and 9 men, mean age: 36 ± 10 years). The echocardiographic characteristics for the study population are shown in Table 1. LVEF was lower in MS patients (63.06 ± 6.54% vs. 65.97 ± 3.92%, p=0.012) but they were in normal ranges. In the analysis carried out between control subjects and MS groups, RV Longitudinal Strain (RVLS) measurement was found to be significantly lower in the patients' group (-18.29 ± 6.75 vs. -31.31 ± 5.24, p=<0.001).

Table 1: Clinical and echocardiographic features of the study groups.

	MS (n=50)	Control (n=35)	p value
Age (years)	38.58 ± 8.51	35.86 ± 10.14	0.184
Female/Male	38/12	26/9	NS
Heart rhythm Sinus Rhythm/ Atrial Fibrillation	17/33	20/0	
LVEF (%)	63.06 ± 6.54	65.97 ± 3.92	0.012
TAPSE (cm)	1.87 ± 0.54	2.59 ± 0.32	<0.001
MVA by Planimetry (cm^2)	0.73 ± 0.16	-	
Mean MVG (mmHg)	13.40 ± 3.74	-	
LA diameter (mm)	49.00 ± 5.95		
LAVI (mL/m^2)	89.38 ± 26.15	-	
TR Vmax (m/s)	3.73 ± 0.86	-	
TVG (mmHg)	59.12 ± 26.72	-	
PAcT	91.34 ± 24.55		
RVLS	-18.29 ± 6.75	-31.31 ± 5.24	<0.001

Abbreviations: LVEF: Left Ventricular Ejection Fraction; TAPSE: Tricuspid Annular Plane Systolic Excursion; MVA: Mitral Valve Area; MVG: Mitral Valve Gradient; LA: Left Atrial; LAVI: Left Atrial Volume Index; TR Vmax: Tricuspid Regurgitation Vmax; TVG: Tricuspid Valve Gradient; PAcT: Pulmonary Artery Acceleration Time; RVLS: Right Ventricle Longitudinal Strain.

From the correlation study we found that there was a moderate correlation between RVLS and TAPSE in patients with MS (r 0.600, p<0.001). A moderate relationship was also shown between RVLS and TR Vmax (r -0.390, p=0.005), TVG (r -0.451, p=0.001), and PAcT (r 0.557, p<0.001). A weak correlation was observed between RVLS and MVA (r 0.323, p=0.022), but we did not find any significant relationship between RVLS and mean MVG (r

-0.168, p=0.242). There was no significant correlation with either LA diameter or LAVI. Results of the correlation analysis are shown in Table 2.

Table 2: Correlations between RVLS and conventional echocardiographic parameters in MS patients.

	RVLS	
	r value	p value
MVA by planimetry (cm^2)	0.323	0.022
Mean MVG (mmHg)	-0.168	0.242
LA diameter (cm)	-0.063	0.664
LAVI (mL/m^2)	-0.228	0.111
TAPSE (cm)	0.600	<0.001
TR Vmax (m/s)	-0.390	0.005
TVG (mmHg)	-0.451	0.001
PAcT	0.557	<0.001

Abbreviations: MVA: Mitral Valve Area; MVG: Mitral Valve Gradient; LA: Left Atrial; LAVI: Left Atrial Volume Index; TAPSE: Tricuspid Annular Plane Systolic Excursion; TR Vmax: Tricuspid Regurgitation Velocity max; TVG: Tricuspid Valve Gradient; PAcT: Pulmonary Artery Acceleration Time.

In a subgroup of patients with normal TAPSE values (TAPSE ≥ 1.7 cm), RVLS was also significantly less compared to controls (-21.38 ± 5.82 vs. -31.31 ± 5.24, p<0.001).

The InterClass Correlation (ICC) showed 0.80 and 0.94 for interobserver and intraobserver variability respectively.

DISCUSSION

Strain echocardiography is a new imaging modality to measure myocardial deformation. It can assess intrinsic myocardial performance and has been recently used in the assessment of RV function [4,8]. In the RV, longitudinal fibers predominate in the free wall and longitudinal shortening contributes more than circumferential shortening to overall RV function, therefore RV Longitudinal Strain (RVLS) can best describe the systolic function of RV [4].

Longitudinal strains are calculated from the percentage of RV free wall shortening from base to apex during systole. Longitudinal RV strains are less affected by overall heart movement and depend on RV loading conditions instead, such as the size and shape of the RV. However, unlike Doppler Tissue Imaging (DTI) strains that are affected by angle, speckle-tracking echocardiographic strain of RV are very dependent on image quality and are influenced by reverberation and other artifacts [7].

The term global RV Longitudinal Strain (RV GLS) usually refers to either the average RV free wall and septal segment or RV free wall segment only. Lately, studies on global peak longitudinal strains of RV that do not include interventricular septum have been carried out, including in populations of patients with heart failure, acute myocardial infarction, pulmonary hypertension, and amyloidosis, as well as in studies which predict the incident of right heart failure after placement of LV assist device. According to a recommendation for the quantification of cardiac chambers using echocardiography by the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI), RVLS of 2D STE is, especially on the RV free wall, reproducible and feasible for clinical use [7].

We assessed the strains of RV free wall in severe MS patients and compared them with control subjects. We found that the RV Longitudinal Strain (RV LS) of MS patients was significantly lower than the control subjects.

In line with the results of our study, Yildirimturk ,et al. revealed that the strains in the RV free wall segment were decreased in moderate to severe MS patients compared to the control group, whereas the value of the RV septal longitudinal strain was similar in both groups with a slightly trend of lower values in MS patients [11]. This finding is most likely due to an increase in RV afterload and a high wall stress due to ventricular dilatation.

This is also corroborated by our findings of a significant correlation of RVLS with TR Vmax, TVG, and PAcT. Kumar, et al. found an inverse (negative) correlation between PA systolic pressure and peak systolic global RV strain. Based on these findings they conclude that RV dysfunction in MS patients is more likely due to the increase in RV afterload rather than intrinsic contractile dysfunction caused by rheumatic processes in the myocardium [3].

There is a physio-pathological process in MS which results in RV failure. Left atrial hypertension in MS patients causes chronic pulmonary venous congestion, which results in pulmonary arterial hypertension. This is because in this phase there is pulmonary arteriolar constriction and obliteration of the pulmonary vascular bed which is subsequently responsible for the increase in RV afterload. The systolic function of RV is afterload-dependent, which is physiologically related to systolic wall stress. RV is sensitive to changes in afterload due to smaller muscle mass and higher wall stress. Right Ventricular Ejection Fraction (RVEF) will decrease by about 10% whenever RV afterload is doubled from 25 to 50 mmHg. A progressive increase in RV afterload results in RV dilatation, RV failure, and systemic venous congestion [11].

However, some authors had suggested that there is a direct involvement of RV in the rheumatic process which lead to myocyte necrosis, and the replacement of myocytes with fibrotic tissues accompanied by calcification is responsible in decreasing myocardial function [3-5,12,13]. Studies by Ozdemir, et al. Kumar et al, and Younan et al. revealed lower global and RV septum strain, but normal RV free wall strain [3,4,14]. Ozdemir, et al. and Younan, et al. explained that the normal RV free wall strain value is related to direct contact of the Inter Ventricular Septum (IVS) with the mitral apparatus through LV fibers so that the rheumatic process can easily extend to IVS segment which resulted in decreased myocardial contraction that is not related to pulmonary arterial hypertension, whereas RV free wall is not affected by rheumatic processes and has normal contraction function [4,14].

RV systolic function is a major determinant of prognosis and survival in MS patients. RV systolic dysfunction develops early before clinical symptoms appear. We have performed subgroup analysis on 30 MS patients with normal TAPSE values (TAPSE ≥ 1.7 cm), which also resulted in significantly lower RVLS values in the MS group compared to the control group with p<0.001.

In our study there was a weak positive correlation between RVLS and MVA planimetry, but not with the mean MVG. Similar results were reported by Tanboga, et al. who found a weak correlation between RVLS and MVA. However, based on their subgroup analysis of MS severity, the value of RV strains did not differ between the two subgroups (mild and moderate). This shows that 2D RV longitudinal strain is not related to the severity of MS. As well known, rest gradients might not reflect the pathophysiological importance of the obstruction and clinical symptoms might not be correlated with the severity of stenosis [9]. Therefore, the possible explanation of lower RVLS in our patients is increased RV afterload (pulmonary hypertension), since we found that the parameters more correlated with RVLS in this study were TR Vmax, TVG, and PAcT.

LIMITATIONS

The small number of patients is the main limitation of this study. The difficulty in getting samples in this study is related to the exclusion criteria used to overcome confounding factors. To confirm the findings of this study, a higher number of samples are needed.

The second limitation is the fact that the deformation parameter used to predict the RV dysfunction is not load-independent. In addition, 2D speckle tracking imaging is said to have a lower temporal resolution compared to the Doppler tissue-based deformation study, thus resulting in less accurate estimates [15]. In relation to this, due to the complexity of RV geometry, real time 3D echocardiography is expected to provide a more accurate evaluation of RV morphology and function. For this reason, further studies to evaluate RV function using 3D echocardiography are still needed. We also did not use the golden standard method to evaluate and confirm our results on RV systolic function, e.g. using cardiac magnetic resonance imaging.

CONCLUSION

Patients with MS had lower RV function using 2D RV longitudinal strain compared to the control group. Two-dimensional RV longitudinal strain, particularly of the RV free wall, appears to be feasible for better assessment of RV function in MS patients.

DECLARATIONS

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Data used in our study were presented in the main text.

Competing interests

Not applicable.

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