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The Correlation Between Mitral Valve Area (MVA) Assessed Using Planimetry, Vena Contracta Width (VCW) and Effective Regurgitant Orifice Area (EROA) Mitral Valve on Right Ventricular Longitudinal Strain (RVLS) in Mixed Mitral Valve Disease due to Rheumatic Heart Disease

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Abstract

Background: Rheumatic heart disease (RHD) is a sequelae of acute rheumatic fever which presents a significant health burden. A total 12.9% of RHD cases are multivalvular lesions, including mixed mitral valve disease. The complexity of mixed mitral valve disease requires further assessment. The hemodynamic consequences are increased of left atrial pressure due to high transvalvular gradient causing pulmonary hypertension and leading to right ventricular dysfunction. The utilization of Right Ventricular Longitudinal Strain (RVLS) are more sensitive when assessed subclinical right ventricular dysfunction compared to standard parameters. It has been known the degree of mitral valve severity through MVA by planimetry, VCW and EROA are associated with RVLS in patients with mixed mitral valve disease due to RHD.

Method: This observational cross-sectional study involved 70 patients diagnosed with mixed mitral valve disease due to RHD at Prof. Dr. I.G.N.G. Ngoerah Hospital, Denpasar with normal right ventricular function (TAPSE >1.75 cm and RV S' > 9 cm/s) and then echocardiographic examination were conducted to assess MVA by planimetry, VCW, EROA and RVLS values

Results: A total of 70 samples were included in the analysis. A significant correlation was found between MVA by planimetry and RVLS (r=0.241; p=0.045), indicating as the the mitral valve area increased, the RVLS were increased. There was no correlation between VCW and RVLS (r=-0.079; p=0.513) and no correlation between EROA and RVLS (r=-0.069; p=0.570). This shows that mitral stenosis lesions are more prone to pulmonary hypertension through increased left atrial pressure and pulmonary artery systolic pressure, thereby increasing right ventricle afterload.

Conclusion: RVLS is an echocardiographic parameter which can assess subclinical right ventricular dysfunction, with MVA by planimetry as a significant correlating factor. On the other hand, VCW and EROA has been found no significant correlation. The application of RVLS can be used in the routine evaluation of right ventricular function and determined a more optimized management strategy for patients with mixed mitral valve disease due to RHD especially mitral stenosis lesions before intervention.

Keywords: Rheumatic Heart Disease; Mixed Mitral Valve Disease; Right Ventricular Longitudinal Strain; Echocardiography; Pulmonary Hypertension

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1. Introduction

Rheumatic Heart Disease (RHD) is a sequelae of acute rheumatic fever which poses a significant burden of health problems. Based on registry 3656 rheumatic heart disease patients from India, most cases are multivalvular lesions, 12.90% of them involved mixed mitral valve disease.[1] This data resembled a study in Indonesia, where 17.7% also had mixed mitral valve disease due to RHD.[2] Currently, the reviews of the pathophysiology, diagnosis and management strategies in severity mixed mitral valve disease are relatively rare and complex, requiring further assessment.[3]

The clinical and hemodynamic consequences of mixed mitral valve disease can be affected by course of the disease, severity of valves, chronicity of the lesion, loading conditions and ventricular compensation that made hemodynamic parameters are unreliable [3]. Mitral regurgitation and mitral stenosis have volume and/or pressure overload resulting increased left atrial pressure, leading to increased pulmonary venous pressure and pulmonary capillaries[2-3].

In later phase, there were more increased in pressure and also changes in pulmonary vascularization, which turn into pulmonary hypertension[4]. Progressive increased in afterload creates mechanical stress on the intersitium of right ventricle and cardiomyocytes causing changes in extracellular matrix components and myocardial fibrosis. Regardless of the etiology, one of the consequences of fibrosis is right ventricular dysfunction [5-6].

Several factors had play role of right ventricular systolic dysfunction in rheumatic heart disease. Decreased right ventricular contractility related to consequences of increased in afterload. On the other hand, direct inflammation of myocardium was suspected in accordance with the natural course of rheumatic heart disease which not only involves valvulitis but also includes rheumatic carditis and progress to myocardial fibrosis[7].

Based on Prihadi et al., Right Ventricular Free Wall Longitudinal Strain (RVFWLS) assessment is more sensitive in detecting right ventricular dysfunction when compared to convetional parameter, due to high predictive value in identifying subclinical right ventricular dysfunction at early phase, when conventional parameters are normal limit[8].

Assessment of valve severity in mixed mitral valve disease quite challenging due to limited only anatomical parameters through Mitral Valve Area by planimetry, Vena Contracta Width (VCW) and quantitative parameter Effective Regurgitant Orifice Area (EROA)[3]. It is known that the severity of mitral stenosis and regurgitation lesions in rheumatic heart disease has a significant correlation with RVLS values[7,9,10].

Currently, the usage of RVLS in RHD was limited. This was first cross-sectional study to assess correlation between mitral valve severity, such as MVA by planimetery, VCW and EROA) on RVLS value in patient with mixed mitral valve disease duet o RHD

2. Method

2.1. Study Design

This an observational study with a cross-sectional design, aimed at determining the correlation between RVLS and mitral valves severity variables (MVA by planimetry, VCW and EROA in patients with mixed mitral valve disease due to RHD.

Participants: A total of 70 consecutive patients with mixed mitral valve disease due to rheumatic heart disease admitted to cardiac polyclinic of RSUP Prof. dr. I.G.N.G. Ngoerah between February 2025 and March 2025 for echocardiography evaluation. Inclusion criteria included patients who were ≥ 18 and < 60 years with normal right ventricular contractility function by conventional echocardiography parameter (TAPSE > 1.7 cm and RV S' > 9 cm/s). Patient who had history of right ventricular myocardial infarct, congenital heart disease, chronic obstructive pulmonary disease, chronic thromboembolic pulmonary hypertension, systemic lupus erythematosus, chronic kidney disease (glomerular fitration rate < 30 ml/min), history of heart surgery, patient with suboptimal echocardiography window for evaluate RVLS and patients who refuse to participate after being given informed consent were excluded. Patient who fullfill inclusion criteria and exclusion criteria are willing to participate in this study for transthoracic echocardiography examination.

Measurements: Right Ventricular Longitudinal Strain (RVLS) is an echocardiographic parameter using speckle tracking method which describes myocardial wall deformation expressed in percentage (%) or fraction. Data were taken from the Apical 4-Chamber (A4C) Focus RV view (50-80 frames/s) for sinus rhythm and 5 consecutive cycle for atrial fibrillation. Furthermore, semi-automatic analysis was performed, by averaging the Peak Systolic Longitudinal Strain value to obtain the RV Free Wall Longitudinal Strain (RVFWLS) value using the GE Vivid S70N machine and then analyzed with GE EchoPAC software.

The planimetry area of the mitral valve (MVA planimetry) is performed through a 2D echocardiographic examination, using multiplanar reconstruction method, which use two orthogonal planes that intersect the ends of the mitral valve and the valve area is measured by planimetry in end diastole (when the mitral valve is widest pen)

Vena Contracta Width (VCW) is a semi-quantitative echocardiographic assessment of severity mitral regurgitation in 2D, which made from two orthogonal planes (Parasternal long axis and A4C) in the systolic phase by measuring smallest width of the distal orifice perpendicular to the direction of the regurgitation jet

Effective Regurgitant Orifice Area (EROA) is a quantitative echocardiographic parameter to assess severity of mitral regurgitation disease in 2D, through calculation of the Proximal Isovelocity Surface Area (PISA) radius of A4C at mid-systolic divided by the peak velocity regurgitation jet with the CW Doppler method

Statistical Analysis: Data were analyzed using SPSS version 26 software. Continous variables were presented as mean ± standard deviation. Categorical variable presented as percentages. The Kolmogorov Smirnov was performed to test normality of distribution data. Correlation analyses between variables performed using Pearson correlation or Spearman correlation, depending on normality distributed data. Linear regression test to determine the parameters that independently affect RVLS values in mixed mitral stenosis patient due to RHD. Statistical significance was set at $p < 0.05$.

Ethical Considerations: The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all participants prior to enrollment.

3. Results

3.1. Sample Characteristics

This study involved a total of 70 samples with mixed mitral valve disease duet o RHD. The Mean age of this study was 47,0 years, and 58 (82,9%) were female. The average RVLS value in all samples of this study is 20,58 ± 4,66. Two-dimensional echocardiographic data mean MVA by planimetry was 1,34 cm^2, VCW was 0,30 cm and EROA was 0,18 cm^2. Characteristic based on severity in this study, there wer more mild mitral regurgitation (54,3%) and severity of mitral stenosis were variable mild (37,1%), moderate (28,6%) and severe (34,3%). Baseline characteristic data were presented in Table 1.

The normality tests using the Kolmogorov Smirnov test shows that all continous variable have non-normal distribution ($p<0.05$), except RVLS shown normal distribution ($p>0.05$).

3.2. Interobserver Variability

Interobserver variability of RVLS with two echocardiologist reviewer using Blant-Altman test (Figure 1) were examined and found no significant difference for interpretation with good agrement in evaluation RVLS (p= 0.082)

3.3. Correlation between VCW and RVLS

Correlation analysis used the Spearman test on VCW and RVLS. There is no significant correlation (r = -0.069; p = 0.570) between the VCW and RVLS value. In this study, mean of VCW wa 0.3 cm belongs to mild mitral regurgitation.

3.4. Correlation between EROA and RVLS

Correlation analysis used the Spearman test on EROA and RVLS. There is no significant correlation (r = -0,079; p = 0.513) between the EROA and RVLS value. In this study, mean of EROA was 0.18 cm belongs to mild mitral regurgitation

3.5. Correlation between MVA by planimetery and RVLS

The analysis of MVA and RVLS used the Spearman correlation test. There is a significant weak positive correlation between MVA by planimetry and RVLS (r = -0, 241; p = 0,045), the higher the MVA by planimetry value, higher RVLS will be. (Table 2)

3.6. Correlation between PASP and RVLS

In sub-analysis, there were moderate negative correlation between PASP and RVLS (r=-0,348; p=0,003), meaning the higher PASP, the lower RVLS tends to be.

The scatter plot curve shows a line towards the upper right (positive correlation), while the curve towards the lower right shows a negative correlation. (Figure 2)

3.7. Multiple Linear Regression analysis between MVA by Planimetry, VCW, EROA and PASP on RVLS

Multiple linear regression analysis shows no significant relationship between VCW, EROA, PASP and LV GLS values (p>0.05). However, there was significant relationship between MVA Planimetry and RVLS. Through the R-square value showing a figure of 0,281, which means that MVA planimetry can explain their role in RVLS by 28,1%, while there are still 71,9% of variables affecting RVLS outside of the variables in this study. (Table 3)

There is a significant positive correlation between MVA planimetry on RVLS. On the other hand there is no significant correlation between VCW and EROA with RVLS.

Table 1 Characteristics of research samples**.**

Characteristic	**Total**
Age (year) (median-IQR)	47.0 (22.0)
Sex (n, %)	
Male	12 (17.1%)
Female	58 (82.9%)
TAPSE (mm) (median-IQR)	21.0 (5.0)
RVS (cm/s) (median-IQR)	12.05 (4.10)
Ejection Fraction (Biplane) (%) (median-IQR)	59.37 (6.37)
PASP (mmHg) (median-IQR)	40.21 (44.07)
MVA planimetry (cm^2) (median-IQR)	1.34 (1.53)
VCW (cm) (median-IQR)	0.30 (0.29)
EROA (cm^2) (median-IQR)	0.18 (0.14)
LAVI (ml/m^2) (median-IQR)	58.72 (61.28)
RVLS (%) (rerata ± SD)	20.58 ± 4.66
Severity of Mitral Regurgitation	
Mild	38 (54.3%)
Moderate	26 (37.1%)
Severe	6 (8.6%)
Severity of Mitral Stenosis	
Mild	26 (37.1%)
Moderate	20 (28.6%)
Severe	24 (34.3%)

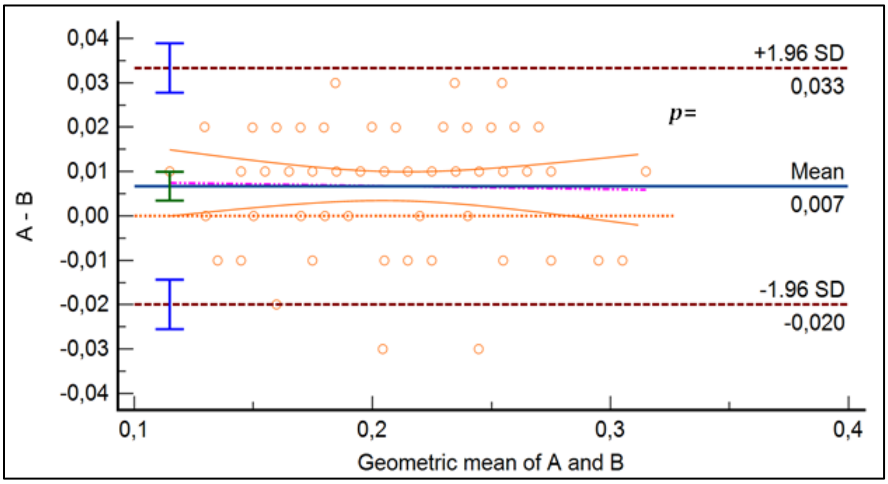

Figure 1 Interobserver Variability using Blant-Altman test.

Table 2 Correlation test between MV planimetry, VCW, and EROA against RVLS value**.**

Variabel	**RVLS (%)**	
	r	p
EROA (cm²)	-0.069	0.570
VCW (cm)	-0.079	0.513
MVA planimetry (cm²)	0.241	0.045*
* Significant (p<0.05)		

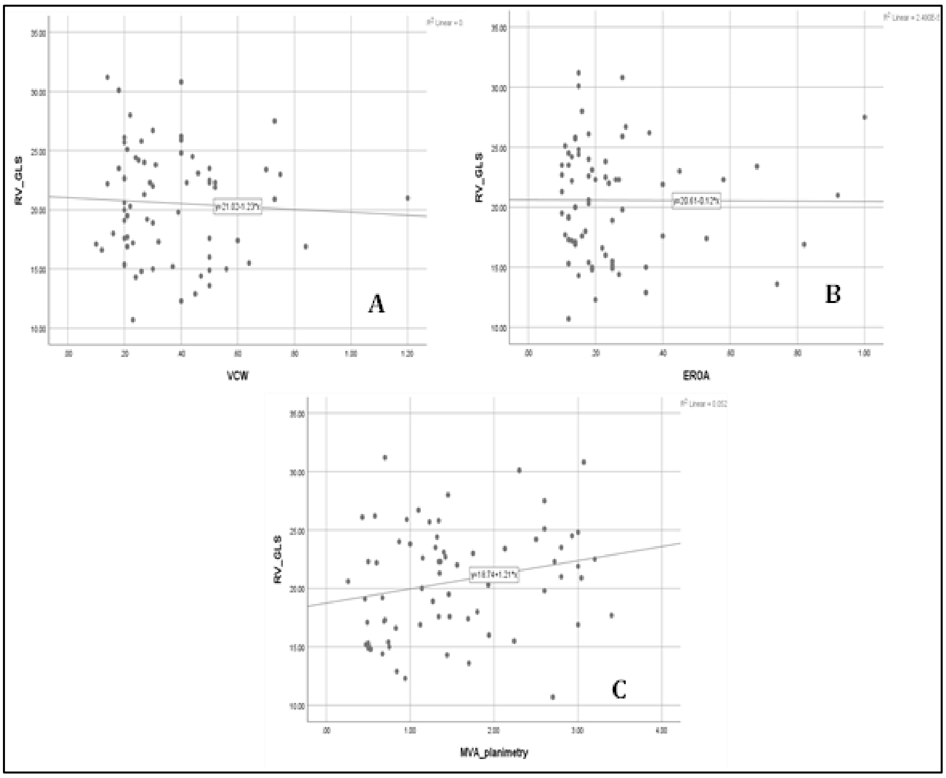

Figure 2 *Scatter plot* graphic shows correlation between RVLS with MVA planimetry, VCW and EROA

Table 3 Linear Regression between MV planimetry, VCW, EROA and PASP against RVLS value.

Variabel	B	95% Confidence Interval (CI)	p
Constanta	12.95	6.58 – 19.32	<0.001*
VCW (cm)	-7.56	-16.50 – 1.38	0.096
EROA (cm^2)	3.87	- 4.6 – 12.43	0.369
PASP (mmHg)	-0.32	-0.74 – 0.11	0.139
MVA planimetry (cm^2)	1.95	0.51 – 3.40	0.009*
*Signifikan (p<0.05); R-square adjusted = 0.281			

4. Discussion

The majority of the samples were female 58 (82.95%) patients, while the remaining 12 (17.1%) patients were male. This is consistent with epidemiological data from Negi et al. showing a predominance of female patients with RHD, may be due to improvement for health care acess and early detection at reproductive age, but specific pathogenesis mechanism was unknown[11]. In this study the average age of patients in this study is 47.0 years, tended to be diagnosed in fourth decade and this not significantly different when compared to national registry for RHD in Indonesia, patient with mixed mitral valve disease have average age around 41.7 years[2]. Natural course of RHD begins with acute rheumatic fever, and most patient asymptomatic and diagnoese when reach adulthood after mulfunction of mitral valve[12].

There is no correlation between VCW and RVLS (r=-0.079; p=0.513), and between EROA adn RVLS (r=-0.069; p=0,570) and more sample with mild mitral regurgitation, which mean severity of mitral regurgitation alone does not seem to correlate with RVLS values in mixed mitral valve disease, as it is known that regurgitation and stenosis lesions should have an equal impact on reducing RVLS values. This result indicate compensate phase of left atrium and ventricle in mitral regurgitation tend to adapts with volume larges volume of regurgitation. Left atrium dilated and accommodates large regurgitant volume without a substantial increase in mean left atrial pressure[13]. Left atrial pressure may begin to increase as result of masking left ventricular systolic or diastolic dysfunction and decreased left atrial compliance[13-14].

In decompensated phase, there was progressive decrease of left ventricular contraction, maladaptive of ventricular dimension with increased systolic wall pressure and filling pressure thus amplifying effect of increased leaft atrial pressure lead to development pulmonary hypertension. Because the right ventricle are more tolerant with volume overload than pressure overload, right ventricle had compensatory mechanism by increase End Diastolic Volume (EDV) for increase contractility through Frank-Starling law[15]. Furthermore by an increase volume and pressure load (severe decompensated mitral regurgitation), right ventricular maladaptation occurs, leading to decreased function and contractility[14]. This is consistent with our study, which some moderate to severe mitral regurgitation with mixed mitral valve disease had a more pronounced decrease in right ventricular contractility (TAPSE < 17 mm), so they were excluded from this study.

A significant weak positive correlation was found between MVA by Planimetry and RVLS values (r = -0.241; p = 0.045). This indicates that the higher MVA planimetry value, more higher RVLS value will be. This was consistent with Poyraz et al. MVA planimetry has moderate positive correlation with RVLS. Unlike other methods, MVA planimetry is not affected by flow conditions, chamber compliance or regurgitation lesion and has good correlation with anatomical area of the valve[7]. Stenosis at level ventricular inflow cause increased left atrial pressure directly, causing transmitting backflow from left atrium to pulmonary veins. Chronic increased of left atrial pressure, leads to impaired left atrial function due to dilatation, fibrosis with decreased of compliance. This process contributes to pulmonary vascular remodeling resulting in a chronic increase in afterload and right ventricular dysfunction[13].

In sub-analysis, there significant moderate negative correlation between PASP and RVLS (r= -0.348: p= 0.003). Indicate that higher PASP, more lower RVLS. This explain influence of adaptive mechanism (heterometric adaptation) by coupling between right ventricular afterload and contractility (RV-PA coupling). However, prolonged activation of adaptive mechanisms, due to progressive increases in pressure overload eventually changes to heterometric adaptation (maladaptive) in form decreased of contractility to right ventricular remodeling due to failure contractility to compensate for excessive high afterload (RV-PA uncoupling)[16]. Progressive increased an afterload causes changes pattern of right ventricular contractility by forming a right ventricular contraction that is less dependent on longitudinal shortening and more on transverse wall movement, causing less deformation of the myocardium at the apex[17].

The results of multiple linear regression test showed only MVA by planimetry was significant relationship between RVLS ($p<0.05$) but not significant with EROA, VCW and PASP ($p>0,05$). These results indicate that severity of mitral stenosis appeared have significant correlation compared with mitral regurgitation in mixed mitral valve disease. This condition can be explained from Mahajan et al., there was decreased in RVLS values before Percutaneous Mitral Balloon Valvuloplasty (PMBV) in patient with severe mitral stenosis, with improvement in RVLS after PMBV[18]. Reduction of right ventricular afterload may explain, through a decrease in PASP, will improve the right ventricular contractility pattern.

However, PASP is not only determinant factor of afterload, other important compnents such as pusatule or pulmonary impedance rather than relying solely on resistive component (pulmonary vascular resistance), which Pulmonary Artery Pulsatility index (PAPi) and PVR measurements were not assessed in this study, and also before interpretation of PASP needs to consider hemodynamic status[19-20].

5. Conclusion

The results of this study indicate that RVLS was echocardiographic parameter had essential role in occurrence of subclinical right ventricular dysfunction in patients with mixed mitral valve disease due to RHD.

MVA by planimetry parameters significantly correlate with the RVLS results, but not with severity mitral regurgitation by VCW and EROA. Severity miral stenosis had significant connection with right ventricle, so RVLS may used for routine evaluation right ventricular function before interventions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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