Original Article

Evaluation of Left Ventricular Size in Early Postoperative Period in Patients with Aortic Regurgitation after Aortic Valve Replacement

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ABSTRACT

Objective: To evaluate the left-ventricular size in early postoperative periodin patients with aortic regurgitation after aortic valve replacement.

Study Design: Retrospective Observational study.

Place and Duration of Study: This study was conducted at the Multan Institute of Cardiology from January 2012 and January 2020.

Materials and Methods: Data was collected from 116 patients with severe chronic aortic regurgitation, who underwent AVR in which transthoracic echocardiograms was performed before and after the surgery. The left ventricular calculations such as LVEDD, LVESD, posterior wall thickness (PWT), and interventricular septum (IVS) were collected as per recommended standards. In our study ≥10% reduction in left ventricular volumes [4] is referred to as reverse left ventricular remodeling as measured by either Teichholz or modified Simpson's methods. Mean ± standard deviation was used for summarizing continuous variables and were compared using t test while Fisher's exact test was used to summarize as count and to compare the categorical variables. The difference between ΔLVESViTeichnolz and ΔLVESViSimpson, and ΔLVEDViTeichnolz and ΔLVEDViSimpson were calculated by estimation of spearman correlations and 95% confidence intervals. Moreover, the assessment of positive and negative agreement by LVEDV and LVESV measurements were done by cross-tabulation of diameter and volume-based left ventricular remodeling individually.

Results: The mean Interventricular septum thickness, left ventricular end-diastolic diameter, indexed left ventricular end-diastolic diameter, left ventricular end-systolic diameter, indexed left ventricular end-systolic diameter, posterior wall thickness, indexed left ventricular mass, left ventricular outflow tract diameter, aortic root diameter and ascending aorta diameter of the patients pre-AVR, was 1.17±0.83, 6.51±1.18, 3.68±1.26, 4.21±1.38, 2.37±1.49, 1.22±0.27, 134.5±13.13, 2.41±1.43, 4.61±0.61, and 4.62±1.25 respectively. The mean Interventricular septum thickness, left ventricular end-diastolic diameter, indexed left ventricular end-diastolic diameter, left ventricular end-systolic diameter, indexed left ventricular end-systolic diameter, posterior wall thickness, indexed left ventricular mass, left ventricular outflow tract diameter, aortic root diameter and ascending aorta diameter of the patients post-AVR was, 1.27±0.29, 5.16±0.51, 2.64±0.47, 3.49±0.94, 2.03±0.48, 0.99±0.09, 115.41±11.12, 2.01±0.11, 3.17±0.31, and 3.03±0.32 respectively.

Conclusion: The outcomes of our study proposed that left ventricular volumes were better than left ventricular diameter measurements for assessment of the reverse remodeling. On the other hand, large scale studies must be conducted in order to conclude whether volumes of the left ventricular also influence outcomes in the long-term.

Key Words: Aortic Regurgitation, Left Ventricle, Aortic Valve Replacement, Reverse Remodeling, Size.

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INTRODUCTION

Being a progressive disorder chronic aortic regurgitation leads to volume overload in the left ventricle (LV). For compensation of this volume overload in left ventricle various changes occurs such as increase in size of left ventricle and eccentric hypertrophy[1] known as remodeling. Geometric changes of shape are included in such alterations in which shape of left ventricle changes from elliptical to spherical shape[2]. The size of left ventricle and systolic function was determined by echocardiography which is also used to assess the valvular disease severity. In patients with aortic regurgitation (AR), echocardiographic estimation of severity of AR, left ventricle dimensions, and the left ventricular ejection fraction (LVEF) are

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essential for assessment of the time of valve intervention and clinical prognosis[1]. Linear left ventricle dimensions are not recommended as data showed that indexed volumes of left ventricle is more sensitive in predicting the cardiovascular events,[3] till date the recommendations for intervention of aortic valve are still based on left ventricle diameters and LVEF. As in linear left ventricle dimensions we assume fixed shape of left ventricle (prolate ellipsoid) which does not measure accurate volume that cannot be applied in the cardiac pathologies like AR. Similarly, the Teichholz and Quinones methods (used for measurement of LVEF and linear left ventricular dimension) are not recommended anymore and volumetric method as modified Simpson's method (biplane methods) are used for clinical uses now a days. The volumetric measurement of left ventricle is used because it does not rely on the geometric shapes and is acceptable for shape alteration. In patients with severe AR underwent aortic valve replacement in first few months after surgery, the size of left ventricle is reduced known as left ventricle reverse remodeling. With improving LVEF and New York Heart Association (NYHA) functional class is related to the reduction in left ventricularend-systolic diameter (LVESD) postoperatively[4-6]. Left ventricular end-systolic volume indexed (LVESVi) is found to be predictor of clinical results according to recent studies[7]. In the past studies there is no data available on the comparison of linear and volumetric dimensions valuation of left ventricular remodeling in severe AR patients, regardless of the extensive use of left ventricular volumetric measures. In our study we compared the left ventricular volumes to left ventricular diameters in order to determine which method better describe left ventricular reverse remodeling in severe AR patients who are receiving AVR.

MATERIALS AND METHODS

Data was collected from 116 patients with severe chronic aortic regurgitation, in Multan institute of cardiology from January 2012 and January 2020, who underwent AVR in which transthoracic echocardiograms was performed before and after the surgery. Patients with complex congenital heart disease or underwent coronary artery bypass grafting, mitral valve repair were excluded from the study. Research Ethics Board of Multan institute of cardiology approved this study. All of the echocardiographic measurements were done in lateral decubitus position. The left ventricularcalculations such as LVEDD, LVESD, posterior wall thickness (PWT), and interventricular septum (IVS) were collected as per recommended standard ofleading-edge method by American Society of Echocardiography [8,9]. Devereux formula was used for measurement of the left ventricularmass. Teichholz formula was used to calculate the LVEDD and LVESD derived indexed left ventricular volume i.e. LVEDDi and LVESDi, respectively [8]. The major axis was from the apical endocardial surface to the surface of the MV in the four chamber view of the apex. On the other hand, minor axis was assessed orthogonally to the major axis at $1/3^{rd}$ of the base of the major axis. The index of left ventricle shape, left ventricle end-systolic and end-diastolic sphericity was measured as ratio of minor-axis to the major-axis length of left ventricle in systole and diastole. The measurement of volume was done on the basis of blood or tissue interface tracings in apical 2 and 4 chamber views. The left ventricle length is the distance between the end of the curve of left ventricle and the middle of this straight line. Modified Simpson's method was used for measurement of as well as LVEF.

In our study ≥10% reduction in left ventricular volumes [4] is referred to as reverse left ventricular remodeling as measured by either Teichholz or modified Simpson's methods. Mean ± standard deviation was used for summarizing continuous variables and were compared using t test while Fisher's exact test was used to summarize as count and to compare the categorical variables. The difference between ΔLVESViTeichnolz and ΔLVESViSimpson, and ΔLVEDViTeichnolz and ΔLVEDVi Simpson were calculated by estimation of spearman correlations and 95% confidence intervals. Harmony among these measurements was evaluated with the help of Bland–Altman analysis. Moreover, the assessment of positive and negative agreement by LVEDV and LVESV measurements were done by cross-tabulation of diameter and volume-based left ventricular remodeling individually. SPSS (version 23) was used for conducting all the calculations.

RESULTS

Overall one hundred and sixteen patients were included in this study. The mean age and BMI of the patients was 48.47±5.47 years and 29.71±2.86 kg/m^2, respectively. There was n=83 (71.6%) males and n=33 (28.4%) females. Aortic dilatation was noted in n=52 (44.8%) patients, endocarditis in n=7 (6.0%) patients, bicuspid aortic valve in n=5 (4.3%) patients, rheumatic/degenerative in n=35 (30.2%) patients and miscellaneous in n=17 (14.7%) patients. During follow-up n=4 (3.4%) patients died. (Table. 1).

The mean Interventricular septum thickness, left ventricular end-diastolic diameter, indexed left ventricular end-diastolic diameter, left ventricular end-systolic diameter, indexed left ventricular end-systolic diameter, posterior wall thickness, indexed left ventricular mass, left ventricular outflow tract diameter, aortic root diameter, ascending aorta diameter, velocity time integral across LVOT, stroke volume, left ventricular end-diastolic volume, indexed left ventricular end-diastolic volume, left ventricular end-systolic volume, indexed left ventricular end-systolic volume, left ventricular ejection fraction by Simpson's biplane method of disks, sphericity index in diastole and sphericity index in systole of the patients pre-AVR was 1.17±0.83, 6.51±1.18, 3.68±1.26, 4.21±1.38, 2.37±1.49, 1.22±0.27, 134.5±13.13, 2.41±1.43, 4.61±0.61, 4.62±1.25, 30.25±6.56, 32.02±4.86, 260.82±25.06, 134.32±23.81, 124.37±27.11, 69.34±10.83, 57.66±16.16, 0.63±0.002 and 0.55±0.31, respectively. While, the mean Interventricular septum thickness, left ventricular end-diastolic diameter, indexed left ventricular end-diastolic diameter, left ventricular end-systolic diameter, indexed left ventricular end-systolic diameter, posterior wall thickness, indexed left ventricular mass, left ventricular outflow tract diameter, aortic root diameter, ascending aorta diameter, velocity time integral across LVOT, stroke volume, left ventricular end-diastolic volume, indexed left ventricular end-diastolic volume, left ventricular end-systolic volume, indexed left ventricular end-systolic volume, left ventricular ejection fraction by Simpson's biplane method of disks, sphericity index in diastole and sphericity index in systole of the patients post-AVR was 1.27±0.29, 5.16±0.51, 2.64±0.47, 3.49±0.94, 2.03±0.48, 0.99±0.09, 115.41±11.12, 2.01±0.11, 3.17±0.31, 3.03±0.32, 19.9±3.36, 75.51±13.64, 179.24±22.31, 87.35±15.11, 100.21±28.21, 48.69±14.57, 45.92±5.99, 0.84±0.009 and 0.49±0.086, respectively. The differences were statistically significant except interventricular septum thickness (p=0.250). (Table. 2).

Agreement between volume and diameter based remodeling using left ventricle end diastolic parameters were shown in table. III. The difference was statistically insignificant. (p=0.081). Agreement between volume and diameter based remodeling using left ventricle end systolic parameter were shown in table. IV. The difference was statistically significant, (p=0.000).

Table No.1: Demographic characteristics of the patients

Variable	Value
Age (years)	48.47±5.47
BMI kg/m^2	29.71±2.86
Gender	
Male	n=83 (71.6%)
Female	n=33 (28.4%)
Etiology of AR	
Aortic dilatation	n=52 (44.8%)
Endocarditis	n=7 (6.0%)
Bicuspid aortic valve	n=5 (4.3%)
Rheumatic/degenerative	n=35 (30.2%)
Miscellaneous	n=17 (14.7%)
Died during follow-up	n=4 (3.4%)

Table No.2: Echocardiographic characteristic of the patients

Variable	Pre-AVR	Post-AVR	P-value
Interventricular septum thickness (cm)	1.17±0.83	1.27±0.29	0.250
Left ventricular end-diastolic diameter (cm)	6.51±1.18	5.16±0.51	0.000
Indexed left ventricular end-diastolic diameter (cm/m^2)	3.68±1.26	2.64±0.47	0.000
Left ventricular end-systolic diameter (cm)	4.21±1.38	3.49±0.94	0.000
Indexed left ventricular end-systolic diameter (cm/m^2)	2.37±1.49	2.03±0.48	0.000
Posterior wall thickness (cm)	1.22±0.27	0.99±0.09	0.000
Indexed left ventricular mass (g/m^2)	134.5±13.13	115.41±11.12	0.000
Left ventricular outflow tract diameter (cm)	2.41±1.43	2.01±0.11	0.000
Aortic root diameter (cm)	4.61±0.61	3.17±0.31	0.000
Ascending aorta diameter (cm)	4.62±1.25	3.03±0.32	0.000
Velocity time integral across LVOT (cm)	30.25±6.56	19.9±3.36	0.000
Stroke volume (mL)	32.02±4.86	75.51±13.64	0.000
Left ventricular end-diastolic volume (mL)	260.82±25.06	179.24±22.31	0.000
Indexed left ventricular end-diastolic volume (mL/m^2)	134.32±23.81	87.35±15.11	0.000
Left ventricular end-systolic volume (mL)	124.37±27.11	100.21±28.21	0.000
Indexed left ventricular end-systolic volume (mL/m^2)	69.34±10.83	48.69±14.57	0.000
Left ventricular ejection fraction by Simpson's biplane method of disks (%)	57.66±16.16	45.92±5.99	0.000
Sphericity index in diastole	0.63±0.002	0.84±0.009	0.000
Sphericity index in systole	0.55±0.31	0.49±0.086	0.000

Table No.3: Agreement between Volume and Diameter Based Remodelling Using Left Ventricle End Diastolic Parameters

Diameter Based	Volume Based		Total	P-value
	No remodeling	Remodeling		
No remodeling	8	18	26	0.081
Remodeling	14	76	90	
Total	22	94	116	

Table No.4: Agreement between Volume and Diameter Based Remodeling Using Left Ventricle End Systolic Parameter

Diameter Based	Volume Based		Total	P-value
	No remodeling	Remodeling		
No remodeling	25	15	40	0.000
Remodeling	8	68	76	
Total	33	83	116	

DISCUSSION

In this study the patients suffering from the severe AR in which AVR was done, improved Simpson's method was used for reclassification of patients not having left ventricular reverse remodeling on the basis of left ventricular diameter into left ventricular reverse remodeling based on left ventricular volume. The outcomes of this study suggested that in patients with severe aortic regurgitation volumetric measurements of left ventricular with improved Simpson's method showed better left ventricular reverse remodeling as compared to linear dimensions. Another previous comparative study[10] was conducted for comparing left ventricular linear volumes and dimensions for measuring left ventricular remodeling in patients with severe aortic regurgitation after performing AVR. A large number of studies involving more than thousands of patients were conducted showed that in the patients with asymptomatic AR at early stages LVESV or LVESD and LVEF are related to the expansion of indications or eventually death[11].

Furthermore, in the symptomatic aortic regurgitation patients underwent AVR, LVEF, and left ventricular dimensions before surgery determines the survival of patients after surgery[7]. Due to this reason the correct identification of left ventricular dimensions is very important in AR patients. left ventricular modifications occur in the chronic AR patients such as left ventricular dilatation and eccentric hypertrophy due to volume overload and left ventricular pressure. Geometric shape alterations occur in left ventricular in case of chroming AR such as elliptical to a spherical shaped LV. In our study it was revealed that improved Simpson's method measures the LVEDV and LVESV well in comparison to diameter-based method. Moreover, the method based on diameter also not estimates the difference in left ventricular indexed dimensions before- and after AVR amongst two methods correctly. Hence outcomes of our study proposed that measurement of volumes of left ventricular done by the improved Simpson's method was better in estimating the shape alteration of left ventricular in AR in comparison to the left ventricular linear dimensions.

Following conception has been previously incorporated in calculations of LVEF. According to various trials the improved Simpson's method showed better results for alteration of shape of LV with fewer geometrical assumptions in comparison to linear dimensions[12]. However, this method depends upon getting clear imaging and good endocardial definition, and for evaluation of volumes of left ventricular and LVEF it is highly recommended technique[8]. Normally in chronic AR patients the shape of left ventricular is said to be rounder[13]. In another study by Bartella et al.[13] angiography was used in severe AR patients for determination of the shape of left ventricular which revealed anterolateral, anterobasal, and inferoapical regions with larger curvature while anteroapical one with lesser curvature. In addition, both eccentric index and circularity index were not sufficient to distinguish shape abnormalities. In same way the sphericity index also failed to distinguish the postoperative remodeling. While, these findings not matched to those of previous studies, which demonstrated left ventricular spherical remodeling in a variety of cardiac pathologies[14-16]. According to the study of Van Dantzig et al.[16], it was found that, more the sphericity of the LV, greater the rate of mitral regurgitation. In addition, the left ventricular sphericity is linked to less exercise and explicit HF in the patients having considerable left ventricular systolic dysfunction[15]. Tischle et al.[17] in his study revealed that left ventricular shape descriptors were very helpful in differentiating normal ventricles from cardiomyopathic ventricles and the shape of the ventricles changed prior to the alterations of left ventricular systolic function become visible. The outcomes of group studies done previously and that of our group study showed significant difference. Primarily, chronic aortic regurgitation patients were not the part of any previous studies and because of AR the sphericity index failed to depict the left ventricular changes properly. Additionally, patients with preserved LVEF were not included in the previous studies while our study included such patients, corroborating this parameter only involved the patients with left ventricular dysfunction[17].

In this study the indexed left ventricular measurements were used which showed better characterization of left ventricular dimensions than the unadjusted left ventricular diameters. In patients with small body structures, the indexed left ventricular dimensions were more accurate than absolute diameters[12]. Brown et al.[12]

in his study also found out that the use of indexed left ventricular dimension after AVR improved the prediction of unfavorable outcomes**.**

CONCLUSION

The outcomes of our study proposed that left ventricular volumes were better than left ventricular diameter measurements for assessment of the reverse remodeling. On the other hand, large scale studies must be conducted in order to conclude whether volumes of the left ventricular also influence outcomes in the long-term.

Author's Contribution:

Concept & Design of Study:	Iftikhar Paras
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