ORIGINAL ARTICLE

IS 3D TRANSTHORACIC PLANIMETRY STILL SUPERIOR OVER 2D ECHO IN RHEUMATIC MITRAL STENOSIS WHEN BOTH AREA AND HEMODYNAMIC PARAMETERS OF SEVERITY ARE IN QUESTION?

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Objectives: The objective of the study was to compare transthoracic 3D planimetry to 2D planimetry in calculating mitral valve area along with correlation of various echocardiographic parameters of severity of mitral stenosis among these modalities.

Methodology: Patients with (RMS) were enrolled. Keeping 2D PHT as reference mitral valve area (MVA) was calculated and it was compared to the results derived by transthoracic 2D and 3D planimetry. Agreement between the 2D and 3D methods was assessed by measuring the intraclass correlation coefficient (ICC).

Results: 51 patients were included. 36 (70.6%) were females; mean age was 33 ± 6 years. Mean gradient was 14.5 ± 3.9 mmhg while mean Pulmonary artery systolic pressure (PASP) was 31.6 ± 6 mmhg. MVA's derived by PHT, 3D planimetry, and 2D were 1.04 ± 0.24, 1.07 ± 0.24, 1.21 ± 0.27 cm^2 respectively. 3D obtained areas were significantly lower compared to 2D ($p< 0.001$) and insignificantly greater from PHT ($p = 0.18$). 3D demonstrated best agreement with MVA PHT (95% limits of agreement: 0.67 to 0.92; ICC 0.84). MVA 3D planimetry and MVA 2D correlated well with PASP and mean pressure gradient but showed weak correlation with left atrium size.

Conclusion: 3D planimetry derived mitral area compared to 2D echocardiography are more in line with PHT calculated area and correlates well to hemodynamic parameters of severity.

Keywords: rheumatic mitral stenosis, mitral valve area, 2D planimetry, 3D transthoracic planimetry, pressure half time

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INTRODUCTION

Rheumatic fever is commonly seen in underdeveloped countries and also shows a high prevalence in Pakistan.[1], There has been a trend in the increase of rheumatic cases in our region especially of mitral stenosis from the past 40 years[2,3] Mitral stenosis has been considered as one of the commonest valvular pathology associated with it and, if not treated timely leads to different complications[4,5] and resultantly high morbidity and mortality.[6] Various treatment options are available including medical management, balloon commissurotomy and finally surgical replacement of the diseased valve with prosthetic one.[7]

Echocardiography is considered as a major diagnostic tool for the assessment and further management of rheumatic mitral valve stenosis. Parameters used to assess severity include measuring mitral valve area, Pressure half time (PHT), mean pressure gradient and maximum pressure gradient across valve.[8] Although these are commonly used to categorize the lesion severity there are certain limitations seen with them. PHT is affected by change in venous return (preload) to the heart or by the compliance of the left ventricle. Moreover, changes in cardiac output and the presence and degree of mitral regurgitation directly influence the trans-valvular gradient seen across the mitral valve.[9]

2 dimensional (2D) echocardiography has been used in the past to measure the mitral valve area by planimetry with the assumption that mitral valve is a flat structure. However, it is largely dependent on operator expertise and experience. In addition, inability to clearly visualize the mitral leaflet tips and poor quality image at parasternal short axis view in some patients can give erroneous results.[10,11] Three (3) dimensional (3D) echocardiography is recently employed to analyze the mitral valve area with the assumptions that it overcomes the challenges linked with traditional 2D echocardiography. Moreover, owing to its high resolution with better image acquisition it helps in locating the ideal plane for crossing the mitral leaflet tips and getting the true mitral valve area.[12] 3D planimetry is considered to

work well in those cases when complex asymmetric geometry of the mitral is encountered like in rheumatic mitral stenosis but still the results are conflicting.[13-15] The objective of the study was to compare transthoracic 3D planimetry to 2D planimetry in calculating mitral valve area along with correlation of various echocardiographic parameters of severity of mitral stenosis among these modalities.

METHODOLOGY

This cross-sectional study was conducted at Rawalpindi Institute of Cardiology, Rawalpindi, Pakistan, from April 2019 to Sept 2019 after approval from the institutional review board. Total 51 patients of ages 18 – 60 years that were having isolated Mitral Stenosis (MS) and in sinus rhythm were included. Rheumatic Mitral stenosis was defined as mitral valve area of less than 4 cm2 with valve having commissural fusion, restricted mobility, early diastolic doming of anterior mitral leaflet, leaflet thickening with or without calcification. Patients excluded were those having moderate to severe mitral regurgitation, aortic stenosis, aortic regurgitation, mild rheumatic mitral stenosis, non-rheumatic mitral stenosis, previous percutaneous trans-venous mitral commissurotomy (PTMC), patients in atrial fibrillation, left ventricle dysfunction, prosthetic mitral valve and pregnancy.

After taking informed consent the patients underwent 2D echocardiography and 3D transthoracic echocardiography (3D TTE) on the same day for evaluation of Mitral valve. Two independent experienced echocardiographers calculated Mitral valve area (MVA) by using 2D planimetry, 3D planimetry and PHT methods and the average of three consecutive measurements was calculated. Both the observers were blinded for the test results.

With the help of Artida (Toshiba Medical Systems) using 2d transducer probe transthoracic 2D planimetry of the mitral valve in parasternal short axis view was done to calculate mitral valve area. Scanning from Left ventricle apex to base was done cautiously in order to collect images at leaflet tips. Further, gain settings were adjusted so that a clear image of the whole contour of the orifice of the mitral valve could be obtained. Then using zoom mode mitral valve was magnified and this image was paused in mid diastole to obtain measurement at the point of greatest leaflet separation. Continuous wave Doppler was used to measure mean trans-mitral gradient in apical 4 chamber view. Pressure half-time (PHT) across the mitral valve was used to estimate mitral valve area by making use of the following formula: 220/pressure half-time. In addition, left atrial size, pulmonary artery systolic pressure was also calculated.[16]

3D transthoracic echocardiography was done on Artida (Toshiba Medical Systems) with 3D transducer PST-25SX, of 2.5MHZ by making use of multiple views, including parasternal long axis (PLAX), parasternal short axis (PSAX), apical four chamber view, to acquire the images as per the guidelines. To get the best image zoom and gain was adjusted. After reconstructing the mitral valve images in multiple planes the valve was bisected perpendicularly taking care of the fact that smallest orifice of the mitral valve is included. Finally with manual tracing of this orifice the MVA using planimetry was calculated.

All the images taken were recorded offline. The values were calculated by two examiners who were blinded to the 2D imaging observations and the findings were averaged to get the final value.

Data was analysed using SPSS-23. Quantitative variables were summarized as mean with standard deviation while qualitative variables were summarized as frequencies and percentages. Pearson's correlation coefficient was calculated to find out the correlation between normally distributed data e.g. Left atrium (LA) size, MVA by 2D and Mean pressure gradient (MPG) while spearman's correlation coefficient was calculated for non-normally distributed data e.g. Pulmonary artery systolic pressure (PASP), MVA by PHT and MVA by 3D, keeping significance level at ≤0.05.

RESULTS

Clinical and echocardiographic data of the population are shown in Table 1.

Table 1: **Clinical and echocardiographic parameters of the study**

Variable	Mean (SD) / n(%)
Total (N)	**51**
Age (years)	33 ± 6
Females	36 (70.6%)
NYHA at time of echo	
II	20 (39.2%)
III	30 (58.8%)
IV	1 (2.0%)
MPG across mitral valve (mmHg)	14.5 ± 3.9
Mean PHT (ms)	219 ± 46
LA size (cm)	45.9 ± 4.9
PASP (mmHg)	31.6 ± 6.0
MVA by PHT (cm^2)	1.04 ± 0.24
MVA by 2D (cm^2)	1.21 ± 0.27
MVA by 3D (cm^2)	1.07 ± 0.24

NYHA= New York Heart Association, MPG= Mean pressure gradient, PHT= Pressure half time, PASP= pulmonary artery systolic pressure, LA = Left atrium, MVA =Mitral valve area

Total patients included in the study after meeting inclusion criteria were 51 with 36 (70.6%) females and

15 (29.4%) males. The mean age of the patients was 33 ± 6 years. Majority of patients 39 (76.5%) were in age group 25 to 40 years while 3 (5.9%) were below 25 years and 9 (17.6%) above 40 yrs. 20 (39.2%), 30 (58.8%) and 1 (2%) patients were classified in NHYA 2, NHYA 3 and NHYA 4, respectively. Patients who were having lower MVA 3D were highly symptomatic (p = 0.003). Average LA size was 45.9 ± 4.9 cm. Mean gradient across mitral valve was 14.5 ± 3.9 mmhg while average PASP among study group was 31.6 ± 6 mmhg.

Mean value of MVA by 3D planimetry, 2D planimetry and 2D PHT was 1.07 ± 0.24, 1.21 + 0.27 and 1.04 ± 0.24 respectively. 3D measurements were significantly lower compared to 2D planimetry (mean difference: - 0.13 ± 0.25 cm^2, n = 51, p<0.001) but these were marginally greater than by 2D PHT (mean difference: - 0.07 ± 0.01 cm^2, n = 45, p = 0.18) but this was insignificant.

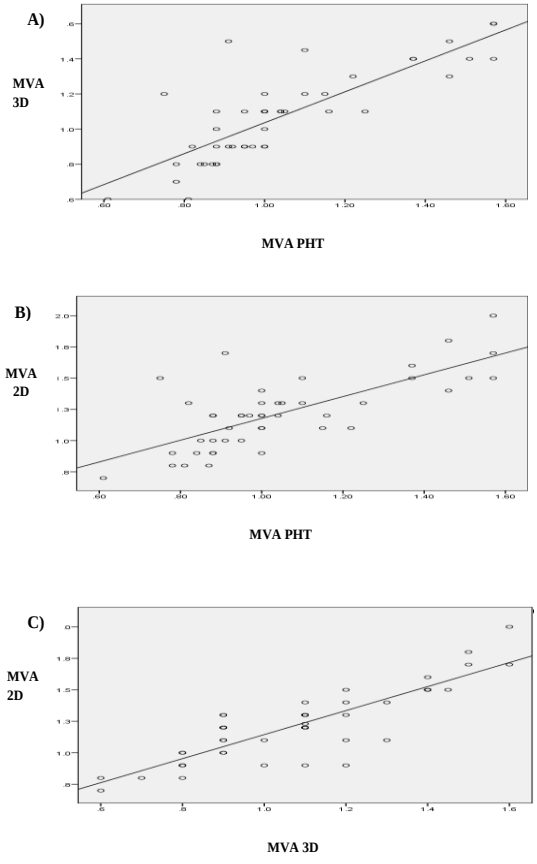

Figure 1: Scatter graphs showing correlation between different methods to calculate mitral valve area. A) Correlation between MVA3D and MVAPHT B) Correlation between MVA2D and MVAPHT C) Correlation between MVA2D and MVA3D

MVA 3D demonstrated the best agreement with MVA PHT (95% limits of agreement: 0.67 to 0.92; ICC 0.84) followed by MVA 2D Planimetry (95% limits of agreement: 0.47 to 0.91; ICC 0.81). Correlations comparing different methods to calculate mitral area are shown in Figure 1 (A-C). Inter-observer and intra-observer agreement showed excellent results for MVA by 3D with ICCs of >0.8 and >0.9, respectively.

Correlations of 3D, 2D planimetry and PHT with the pulmonary artery systolic pressure (PASP), LA size and Mean pressure gradient are shown in Table 2.

Table 2: Correlation between mitral valve area and hemodynamic parameters among pressure half time, 2D planimetry and 3D planimetry modalities

Parameters	MVA by PHT	MVA by 3D Planimetry	MVA by 2D Planimetry
MPG	−0.492 [p=0.01]	−0.553 [p<0.01]	−0.496 [p<0.01]
PASP	−0.627 [p<0.01]	−0.680 [p<0.01]	−0.614 [p<0.01]
LA Size	−0.358 [p=0.016]	−0.292 [p=0.038]	−0.207 [p=0.146]

2D = two dimensional, 3D = three dimensional, MVA = mitral valve area, MPG = mean pressure gradient, PASP = pulmonary artery systolic pressure, LA = left atrium

DISCUSSION

To delineate mitral valve area and to plan further management of rheumatic mitral stenosis both 2D and 3D methods are being used nowadays. 2D methods include measuring PHT, planimetry. There are certain limitations for which these methods cannot be generalized for every patient. Moreover, inaccurate quantification of severity of mitral stenosis can dramatically change the course of management.[17]

The introduction of 3D echocardiography has thought to overcome the limitations associated with 2D evaluation especially related to the geometry of the mitral valve including planimetry derived mitral valve area. In addition, it might also help by looking at the morphology of the mitral valve before balloon mitral valvuloplasty.[18]

Our study demonstrated that mitral valve areas calculated from 3D planimetry were low compared to 2D planimetry but were almost similar to the ones derived from PHT (Figure 2).

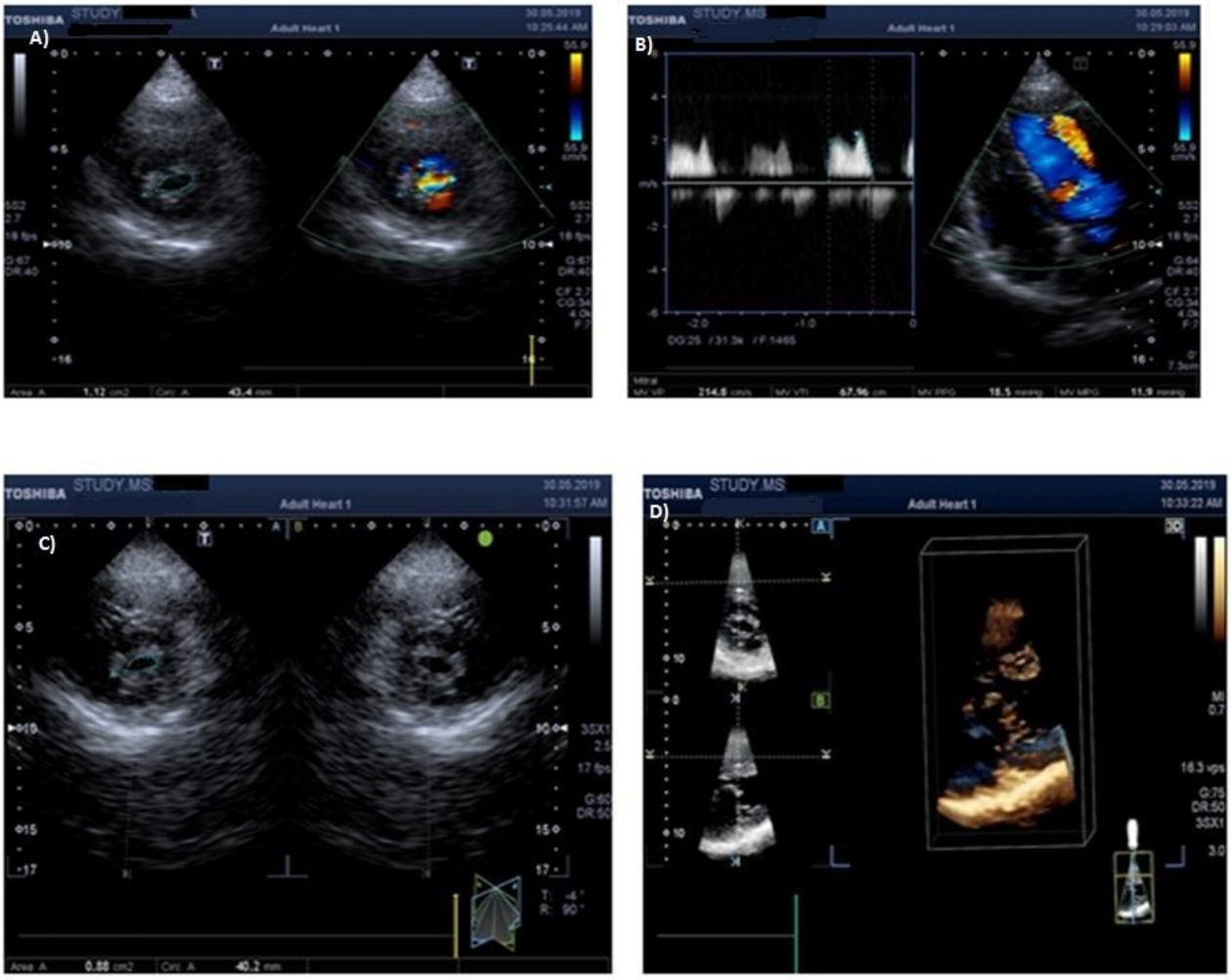

Figure 2: (A, B) Mitral valve area as calculated by 2D planimetry and by PHT method. Area calculated shows moderate mitral stenosis however mean pressure gradient across valve is 11.9 mmhg which suggests a severe stenosis. (C, D) 3D Images taken from the same patient demonstrates the area of 0.88cm2 which makes it a severe lesion and also supports the gradient calculated by 2D method suggesting that 3D can help in clarifying the mixed results obtained by conventional methods

This is in contrast to the study done by Bleakley et al.[19] which showed that 3D derived areas showed the smallest estimate compared to both 2D planimetry and PHT values. The smaller values calculated by 3D method can be explained by the availability of adjustable dataset which helps the echocardiographer to accurately reconstruct the geometry by intersecting at the true orifice of the valve. Additionally, since pathophysiology of rheumatic mitral stenosis is linked to commissural fusion so it is sometimes difficult to look for it in routine transthoracic views. However, 3D images with better resolution can easily identify degree of fusion from different dimensions among leaflets throughout the cardiac cycle.[20] Almost similar areas by PHT and 3D in our case can be explained by the fact that the patients included were isolated cases of mitral stenosis and all of the patients were in sinus rhythm so the hemodynamic influence on PHT was almost negligible.

Studies have shown that 3D transesophageal echo provided excellent results in measuring the true mitral valve area in rheumatic mitral stenosis but in case of 3D transthoracic echo there have been conflicting results. Few studies[21,22] suggest that owing to low spatial resolution of the images and presence of possible multiple types of artifacts during image acquisition results can vary. On the contrary, Sugeng et al.[23] showed that compared to conventional methods (2D planimetry, PHT and PISA) 3D transthoracic echocardiography resulted in findings which were

almost similar to the invasively derived one by formula. Zamorano et al.[24] also concluded 3D to be useful and accurate technique. Our study also showed mitral valve areas by PHT were more in agreement to the 3D TTE derived one as compared to 2D planimetry.

We also looked into echocardiographic parameters which suggest severity of the stenosis. Interestingly, both 3D and 2D planimetry showed significant correlation with both PASP and MPG across the stenotic valve but LA size was only significantly correlated to the 3D method. This suggests that 3D also links well with the hemodynamic parameters of severity and can predict the chance of having long term complications, which might occur, at an earlier stage and can guide the physician to intervene in the initial stage of the disease process. However, future studies with including more variables of hemodynamic severity may be required before any assumptions can be made.

There were certain limitations of this study. Firstly, only isolated RMVS cases were included in study so further studies with mixed and multi-valvular patients are required before the results can be generalized. Second, as there are chances of various image artifacts during evaluation of valve area so methods should be designed to reduce the artefactual distortion of the geometry in order to minimize error in 3D image acquisition. Third, since PHT itself can be influenced by hemodynamic parameters so those cases with associated AF and LV dysfunction may require invasive measurement of mitral area with Gorlin's formula.

CONCLUSION

3D planimetry compared to 2D echocardiography not only helps in clarifying questionable severity of mitral area in rheumatic mitral stenosis but also provides additional support by correlating well not only to PHT derived area but also with some of the hemodynamic parameters of severity.

AUTHORS' CONTRIBUTION:

MA: Concept and design, data acquisition, interpretation, drafting, final approval, and agree to be accountable for all aspects of the work. MA, KA, AU, SSS, RK: Data acquisition, interpretation, drafting, final approval and agree to be accountable for all aspects of the work.

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