ASSESSMENT OF TTK CHITRA MITRAL PROSTHETIC VALVE AT REST AND EXERCISE BY ECHOCARDIOGRAPHY

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ABSTRACT

BACKGROUND
Assessment of prosthetic valve by echocardiography remains an important aspect in prosthetic valve follow up. Changes in transvalvular gradient during increase in heart rate (HR) is a common phenomenon. In this context the study was undertaken to evaluate the transvalvular gradient during simple exertion in TTK Chitra Mitral Valve Prosthesis (TCMVP).

The aim of this study was to investigate the normal Doppler parameters like Prosthetic Valve Peak Velocity (PVPV), Prosthetic Valve Peak Gradient (PVPG), Prosthetic Valve Mean Gradient (PVMG), Pressure Half Time (PHT), Effective Orifice Area by Continuity Equation (CE) & Orifice Area PHT of TCMVP, Pulmonary Artery Systolic Pressure (PASP) and its changes with exercise.

MATERIALS AND METHODS
70 patients who had undergone mitral valve replacement with TCMVP on routine follow up were taken up for study. Echocardiographic analysis of Prosthetic valve parameters was done. Patients were asked to climb up and down two floors which leads to HR increase and same echo parameters were repeated. Effective Orifice Area by Continuity Equation (CE) and PHT are calculated both at rest and exercise.

RESULTS
Out of the 70 patients studied, 51 were female & 19 were Male. 16 patients were on 25 M, 37 were on 27 M & 17 were on 29 M TCMVP. PVPV at rest was 1.66±0.25 m/sec and increased to 1.99±0.3 m/sec after exercise. The PVMG at base line and after exercise were 4.61±2 mmHg and 6.03±2.4 mmHg respectively. PASP increases from 26 .5±5 mmHg at to 36.8±6 mmHg after exercise. Effective orifice area by continuity equation is 1.70 cm^2 at rest and 1.80 cm^2 at exercise. Mitral Prosthetic Valve Area calculated from pressure half time at rest is 2.06 cm^2 which changed to 2.46 cm^2 with exercise. The mean gradient of 25M, 27M and 29M valves are 6.6, 4.09 and 3.89 mmHg respectively at rest and increased to 8.23, 5.47 and 5.21 mmHg with exercise.

CONCLUSION
The basic haemodynamic parameters of TTK Chitra valve of different sizes are comparable with that of other types of prosthetic valves. The gradient across the larger size valves is lower when compared to smaller sized valve. There is a significant elevation of the mean and peak valve gradients with exercise.

KEYWORDS
Prosthetic Valve, TTK Chitra Valve, Echocardiography, Continuity Equation.

BACKGROUND
The incidence and the prevalence of the Rheumatic Heart Disease in India are high when compared to other developed countries. Rheumatic heart disease accounts for the major indication for valve replacement in India. Mitral replacement is usually done for patients with rheumatic heart disease with mitral stenosis or mitral regurgitation or combined mitral stenosis and mitral regurgitation. These patients are usually <50 years and choice of valve is Mechanical rather than Bioprosthetic. Since the Indian developed TTK Chitra[1] valve is cheaper than any other available mechanical valve, it is used widely in our country.

Evaluation of Prosthetic Valve can be done by echocardiography and fluoroscopy. Doppler echocardiography which is a pivot in Prosthetic valve evaluation,[2] gives the idea of haemodynamics across the prosthetic valve. In our study we tried to get baseline Doppler echocardiography parameters of the patients who are replaced with TTK Chitra valve in Mitral Position at rest and after exercise.

MATERIALS AND METHODS
The study was conducted in Department of Cardiology, Chengalpattu Medical College between December 2016 to May 2018. This is a single centre, prospective observational study. About 70 patients with TTK Chitra prosthetic Mitral Valve on regular anticoagulation therapy without any clinical evidence of heart failure who came to our cardiology department for follow up were studied. Patients with Double

Valve Replacement, Atrial Fibrillation, Other significant valvular disease, less than 3 months of valve replacement, Coronary artery disease, Chronic obstructive Pulmonary Disease., Left ventricular ejection Fraction <50%, Chronic Kidney Disease, Recent evidence of thromboembolism, not able to exercise or Not willing for exercise were excluded from the study.

Esaote My lab Gold Echocardiography machine is used for examinations is used.

The Left ventricular diameter is measured just below the aortic valve with freezing of image at mid systole from endocardium to endocardium in the Parasternal Long axis view. Three values are taken and averaged.

In apical 4 chamber, the colour Doppler interrogation is done across the mitral prosthetic valve. Continuous wave recording is done along the Colour Doppler flow jet to get the Mitral prosthetic valve Velocity Time Integral (VTI), Peak and the Mean Velocities. The Peak and the Mean gradient are calculated from the Bernoulli's equation.[3]

Pressure Gradient = 4 x Velocity [2]

The Pressure Half time is calculated in msec by tracing the map from the peak velocity along the slope. The calculated Mitral orifice Area from the pressure half time is done using the formula.

Calculated orifice area = 220/ pressure half time.

The systolic Pulmonary artery pressure is calculated using the formula.

Pulmonary Artery systolic Pressure = TRPG + Right Atrial Pressure.

Then the Apical 5 chamber view the pulse wave Interrogation is done 3 mm below the aortic annulus to get the Left ventricular outflow tract VTI.

The effective orifice area is calculated by the using continuity equation[4] by

MV area = 0.785 x LVOT diameter^2 x VTI_{LVOT}/VTI_{MV}

Then the Patients are asked to climb up and down 2 floors. After the exercise the patients are immediately examined for the heart rate, VTI of the prosthetic valve. Its prosthetic valve peak velocity, Prosthetic valve Peak gradient, Mean gradient & Pressure Half Time are measured.

Statistics Analysis
Descriptive statistics are expressed using mean and standard deviations for continuous variables and frequency and percentage for discrete variables. Paired sample t test is used for comparison of Means of continuous variable. Pearson correlation used to find correlation between continuous variables. Simple linear regression is used to find the relation between variables. If more than 3 groups were compared, ANOVA is used. The level of statistical significance was 0.05. SPSS statistical software version 19.0 is used for Statistical analyses.

RESULTS
70 patients who had been replaced with TTK Chitra Prosthetic valve is studied in detail. 51 patients were female, and 19 patients were male. 30 Patients belongs to age group

less than 30 years, 25 belong to age group in between thirty and forty years and only 15 Patients belong to age group more than 41 years. 24 Patients had the prosthetic valve implantation within a year and patients who had the prosthetic valve implantation between 1 to 2 years ago were 19 patients. patients who had prosthetic valve implantation of 2-3 years, 3-4 years, 4-5 years and > 5 years were 9, 7, 9 and 2 respectively

25M were used in 16 patients (23%), 27 M were used in 37 patients (53%) which contributes the major percentage and 29 M valve were used in 17 patients (Figure 1).
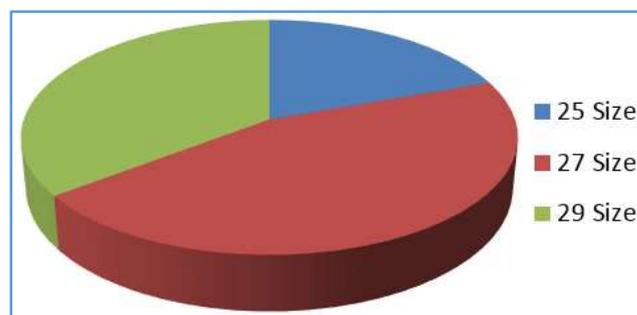

Figure 1. Distribution of Size of Valve

Doppler Parameters at Rest
The Heart rate at rest varies between 60 to 101 /min. The peak velocity at rest is 1.66±0.25 m/sec. The peak gradient across the prosthetic valve at Rest is 11.10±3.71 mmHg. The Mean prosthetic valve gradient is 4.61±2.05 mmHg. The mean of pulmonary arterial systolic pressure was 26.50±5.3 mmHg

Mitral Prosthetic Valve Orifice Area at Rest
The Mitral prosthetic valve orifice area calculated by Pressure Half Time is 2.06 ±0.29 cm^2 with minimum valve orifice area 1.59 cm^2 and the Maximum orifice area 2.99 cm.^{2} The Effective Orifice Area calculated by continuity equation is 1.70 cm^2 with the standard deviation of 0.23 cm^2 with minimum valve orifice area of 1.12 cm^2 and Maximum orifice area of 2.24 cm^2

Doppler Parameters at Exercise
The heart rate increases to a mean of 98.51/min with dynamic exercise with the minimum heart rate of 80/min to maximum heart rate of 127/min. The Peak velocity at exercise is 1.99±0.30 m/sec. The Peak prosthetic valve gradient is 15.89±5.01 mmHg. The Mean prosthetic valve gradient is 6.03 mmHg with that standard deviation of 2.4 mmHg. The average pulmonary artery systolic pressure is 36.81±6.4 mmHg with exercise.

Mitral Valve Orifice Area at Exercise
The mean Mitral Valve orifice area calculated from Pressure Half Time is 2.46 cm^2 with Standard deviation of 0.51 cm^2. The Maximum and minimum valve area are 4.27 cm^2 and 1.65 cm^2 respectively. The Effective orifice area calculated by Continuity equation is 1.80±0.22.

Comparison of Doppler Parameters between Rest and Exercise

The peak velocity increases from 1.66 m/sec to 1.99 m/sec with exercise which is statistically significant. The increase in the Peak and mean gradient are statistically significant. The pulmonary artery systolic pressure increases from 26.50 mmHg to 36.81 mmHg which is statistically significant (P<0.01).

Comparison of Mitral Valve Orifice Area between Rest and Exercise (Figure 2).

Effective orifice area calculated by continuity equation is 1.70 cm ^{2} at rest and 1.80 cm ^{2} at exercise. It is not having much change with the exercise (Difference = 0.07 cm^2).
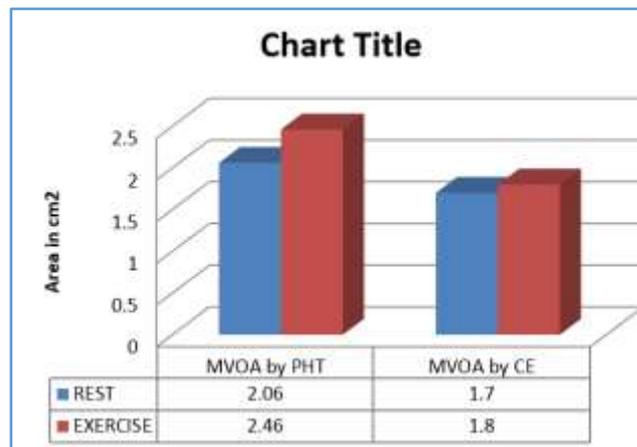

Figure 2. Change in Orifice Area with Exercise

Analysis with Different Valve Sizes

Analysis of Doppler parameter of various size of valve is shown in Table 1 and prosthetic valve orifice is shown in Table 2.

	25 M		27M		29M	
	Mean at Rest	**Mean at Exercise**	**Mean at Rest**	**Mean at Exercise**	**Mean at Rest**	**Mean at Exercise**
Heart Rate (/min)	79.12	97.32	76.1	99.21	77.72	98.12
Peak Velocity (m/sec)	1.90	2.21	1.62	1.95	1.56	1.87
Peak Gradient (mmHg)	14.44	19.53	10.49	15.21	9.73	13.98
Mean Gradient (mmHg)	6.61	8.23	4.09	5.47	3.89	5.21
PASP (mmHg)	27.32	37.32	25.77	36.08	27.320	37.92
Table 1. Rest and Exercise Comparison of Doppler Parameters in 25 M, 27M, 29M Valves						

	25 M		27M		29M	
	Mean at Rest	**Mean at Exercise**	**Mean at Rest**	**Mean at Exercise**	**Mean at Rest**	**Mean at Exercise**
Area calculated by Pressure Half Time (cm^2)	1.75	1.99	2.09	2.53	2.31	2.79
Effective Orifice Area by Continuity equation (cm^2)	1.49	1.58	1.71	1.76	1.91	2.11
Table 2. Comparison of Mitral Valve Orifice Area between Rest and Exercise in 25 M, 27M, 29M Valves						

Comparison between 25M, 27M, 29M Valve at Rest

The data from all three types of valves 25M, 27M, 29M at rest were analysed with ANOVA. The Peak Velocity, Peak prosthetic valve gradient, mean prosthetic valve gradient significantly changes with Valve size. These parameters are inversely proportional to the valve size i.e. the gradient increases with small valve size. These is no significant difference in Pulmonary arterial systolic pressure between different valve size.

Comparison between 25M, 27M, 29M Valve at Exercise

The results are similar to the value at rest. There is a significant difference in Peak Velocity, Peak prosthetic valve gradient, mean prosthetic valve gradient between the various valve size but there is no significant difference in Pulmonary arterial systolic pressure.

DISCUSSION

TTk Chitra valve is comparable to the other valves which came from the 10 year follow up by Srinivasan Muralidharan et al.[5] The 10-year survival in mitral position for the TTK Chitra valve is 60.5% when compared to Medtronic hall which has 58% survival and the St Jude valve which had a 10-year survival of 71%.

Rest Data Comparison with Earlier Studies for TTK Chitra Valve

The normal Doppler parameters for TTK Chitra valve is studied rarely. In Namboori[6] et al 40 patients were studied of which 13 patients were 25M, 22 patients were 27M and 5 Patients were 29M. For 25 M patients the peak and mean gradient was 5.09 mmHg and 12.6 mmHg but in our study 16 patients had 25 M valve and their mean gradient was 6.61 mmHg which was 1.5 mmHg higher than that study. The peak gradient for 25 M prosthetic value in our study is 14.4 mmHg which was higher by 1.8 mmHg when compared to that study.

For 27 M valve the Mean and peak gradient were 3.72 mmHg and 10.3 mmHg respectively in their study whereas in our study it was 4.09 mmHg and 10.49 mmHg. The difference was 0.37 mmHg and 0.19 mmHg. These differences are only less than 1 mmHg.

For the 29 M valve we studied 17 patients and they studied only 5 patients. The Peak and the mean gradient were 3.26 mmHg and 10.0 mmHg respectively in their study. The Peak and the mean gradient in our study are 3.89 mmHg and 9.73 mmHg respectively. The difference with the peak gradient is negligible. Similar to our study the effective valve area calculated by continuity equation is lower than the area calculated by Pressure half time method.

In 2004 Pawan Kumar et al[7] from the cardiovascular department studied patients with TTK Chitra valve. The patients with 25 M had a mean gradient of 5±3 mmHg and the value for the 27 and 29 M valve were the same 4±2 mmHg. They did not publish the pressure data in decimals

however the mean pressure for 25M and 27M were same as ours but the mean pressure for 29M valve was higher than our study.

Maria Aziz[8] studied in 60 patients for the normal Doppler parameters of the prosthetic valve TTK Chitra valve in Mitral position. In his study there were more Male patients than female (68% vs. 32%) just opposite to ous (28% vs. 78%). He studied all types of valves including 9 patients with 31M which is not present in our group and earlier studies. The Mean gradient for 25M, 27M, 29M, 31M were 7.93 mmHg, 5.3 mmHg, 4.3 mmHg and 3.05 mmHg respectively. In the present study it was 6.61 mmHg, 4.09 mmHg, 3.89 mmHg for 25M, 27M, 29M. The gradients in their study was higher when compared to the present study. The data for 31M was available from his study and it is 3.05±0.5 mmHg Mean gradient and 6.1±1.7 mmHg Peak gradient.

Rest Data Comparison with Other Mechanical Valves

Valve Size	Peak Gradient mmHg	Mean Gradient mmHg	Peak Velocity m/sec	Pressure Half Time msec	Effective Orifice Area cm^2
25	12±4	6±2	1.75±0.38	99±27	1.72±0.6
27	10±4	5±2	1.6±0.49	89±28	1.81±0.54
29	7.8±2.9	2.83±1.27	1.37±0.25	79±17	2.1±0.43
31	6±3	2±1.9	1.41±0.26		
Table 3. Normal Doppler Values for Bjork Shiley Valve [9]					

When compared to the Bjork Shiley valve (Table 3) TTK Chitra valve has higher peak gradients whereas the mean gradient are comparable in both group.

Valve Size	Peak Gradient mmHg	Mean Gradient mmHg	Peak velocity m/sec	Effective orifice area cm2
25				1.35±0.17
27	11±4	5±1.82	1.61±0.29	1.67±0.17
29	10±3	4.15±1.8	1.57±0.29	1.75±0.24
31	12±6	4.46±2.2	1.59±0.33	2.03±0.32
Table 4. St. Jude Medical Mechanical Valve at Mitral Position				

The valve orifice area of the TTK Chitra is comparable to the St Jude valve[10] (Table 4) in mitral position for all three types 25M, 27M, 29M valves. The peak and mean gradient across the 25M, 27M, 29m does not shows much variations.

When compared with the Omnicarbon valves the mean gradient of the TTK Chitra prosthetic valve are more or less the same for 25M and 27 M valve. The mean gradient for the 29M in Omnicarbon valve is higher than that of TTK Chitra valve.

Comparison of Peak Gradient, Velocity and Mean Gradient after Exercise with Other Studies

Weiss et al[11] evaluated the Mechanical and The Peak pressure gradient increases from 9±2 at rest to 16±3 in patients with Mechanical prosthetic valve. But in Patients with Bioprosthetic valve the valve at rest and exercise are 14±8 to 21±9 (p<0.012). The Mechanical valves used in the study were 5 St Jude, 5 Omnicarbon and 2 Starr Edwards.

In our study the peak gradients (11 mmHg) at rest and exercise (16 mmHg) were comparable to the Mechanical valves of other company but not with the gradient of Bioprosthetic valves.

Nellesen et al[12] studied the rest and exercise haemodynamics before and after valve replacement. The Mean gradient across the Mitral prosthetic valve was 5±2 mmHg at rest and increased to 9±4 after exercise. The mean heart rate at rest and exercise were 74±17 beats per minute to 138±29 beats/minute. Here the rise in the gradient is higher as the patients are subjected to maximum exercise and their heart rate increase after exercise is higher.

Jeffrey et al[13] in 1991 studied the changes in the gradient for patients with mitral stenosis and Mitral Valve replacement. The mean gradient increases from 5±2 mmHg at rest to 8 ±3 mmHg at peak exercise. The peak gradient increases from 12±5 mmHg to 18±7 mmHg which is comparable to our study (11.1 mmHg to 15.8 mmHg).

In the study by Tatineni et al,[14] St. Jude Medical mechanical prosthetic heart valves had rest and exercise mean gradient 2.5 mmHg and 5.1 mmHg respectively. The mean gradient at rest was 5.1 mmHg and rose to 7.0 mmHg in Medtronic Hall mitral prosthesis valve. In the present study the rest and exercise pressure gradient (4.6 vs. 6.0 mmHg) resembles that of the Medtronic hall prosthetic valve.

The change in the Doppler parameters on exercise for different valve size is done by Ulus AT[15] et al. For the patients with 29M valve the peak pressure at rest and exercise were 11.6±4.7 mmHg, 16.2±6.8 mmHg respectively. In our study for the patients who had 29 M valve the rest and exercise peak gradient are 9.73 and 13.98 mmHg. So, in 29M group the values in TTK Chitra valve is little lower than the previous study. The gradients for 25 M valve are comparable.

Dressler FA[16] et al in his study found that the prosthetic valve Mean gradient at Mitral Position during rest was 2.3-7.1 mmHg and it increased to 5.1-16.5 mmHg with exercise. In the present study the mean Prosthetic valve gradient is 4.73 mmHg at rest and 6.22 mmHg at exercise. The rise in the mean gradient was higher than in our study.

In The study by Fam CN et al[17] the rise in the Medtronic Hall valve is little lower when compared to our study with TTK Chitra valve.

Prosthetic Valve Orifice Area and Exercise

In the present study, the mitral prosthetic Valve area calculated from Pressure half time at rest is 2.06 cm^2 which is changed to 2.46 cm^2 at exercise. It shows a false increase of 0.4 cm.^{2} But the effective orifice area calculated by continuity equation change with the exercise by only 0.1 cm^2

The Doppler Pressure Half time Method of Mitral valve area determination depends on the Atrioventricular compliance[18] as well as peak transmitral gradient. The Continuity method of Mitral valve area determination is based on the Mass conservation and may be less sensitive to changes in the haemodynamic state. During exercise, the cardiac output increases, gradient increases but the AV compliance reduces. The Mitral valve area calculated by Pressure half time increases but The Mitral Valve area calculated by continuity equation remains constant.

Pulmonary Artery Systolic Pressure Changes with Exercise in Prosthetic Valve Patients

There is a elevation of pulmonary arterial systolic pressure[19,20,21] with exercise after valve replacement irrespective of the valve, aortic or mitral. The mean increases in the pulmonary artery systolic pressure (PASP) was from 24±7 mmHg at rest to 51±2 mmHg with peak exercise and the corresponding increase in the heart rate was 74±8 beats/minute to 127±16 with exercise. In the present study the PASP increases from 26 mmHg to 36 mmHg. The rise in our study was lower as in our patients, heart rate rise is lower when compared to them.[12]

In the study by Jeffrey et al.[13] Heart rate increases from the baseline of 79±9 to a heart rate of 104±21 beats / minute which more or less similar to our study. The PASP pressure rose from 28±8 mmHg to 39±15 mmHg which was comparable to our study.

The limitation of study are, It is a single centered study involving small sample size and Exercise testing is not done by Treadmill Test.

CONCLUSION

The study provides the Doppler echocardiographic parameters and Effective Orifice Area for TTK Chitra Valve of different sizes at mitral position. The basic haemodynamic parameters of TTK Chitra valve are comparable to those of other types of prosthetic valve. The gradient across the larger size valves is lower when compared to smaller sized valve.

There is a significant elevation of the mean and peak valve gradients after exercise (by 1.42 mmHg and 4.79 mmHg respectively). The mitral valve orifice area calculated by the continuity equation is reliable after exercise. This observation helps us to get a reference value for TTK Chitra Prosthetic Valve during dynamic exercise.

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