

Evaluation of the Effect of Percutaneous Balloon Mitral Valvuloplasty on Right Ventricular Function Using 2d Speckle Tracking Echocardiography

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Abstract

Background; Mitral stenosis (MS) is a disabling and eventually lethal disease, The great majority of cases in adults are due to rheumatic heart disease. Right ventricular (RV) function plays an important role in development of clinical symptoms and prognosis in patients with MS. **Aim and objectives;** We aimed to evaluate right ventricular functions by speckle tracking-echocardiography in patients with severe rheumatic mitral stenosis before and after percutaneous mitral balloon valvuloplasty, **Subjects and methods;** This was prospective study, was carried out in in Cardiology Department, national heart institute (NHI) and Benha university hospital on 100 patients with severe mitral stenosis who performed Percutaneous Balloon Mitral Valvuloplasty (PBMV). In our study we excluded patients with severe tricuspid regurge, patients who showed signs of concomitant aortic disease, patients with coronary artery disease, pericarditis and myocarditis. All subjects were evaluated by history taking, clinical examination, routine laboratory investigations, 12-lead ECG, Conventional transthoracic echocardiography 2D echocardiography, Doppler Tissue Imaging (DTI)) and 2D speckle tracking echocardiography (STE) before and three months after percutaneous mitral valvoplasty, **Result;** Our study included one hundred patients with severe mitral stenosis, 40 males and 60 females. Our study demonstrated that Global RV systolic strain as well as, segmental strain at basal, mid and apical septum showed a statistically significant rise after BMV. TAPSE and FAC also increased significantly post BMV, **Conclusion;** RV systolic function is impaired in patients with severe MS and can be assessed by global and segmental RV strain before the appearance of clinical signs of systemic venous congestion, After Percutaneous Balloon Mitral Valvuloplasty (PBMV), it was associated with significant rise in the Global RV systolic strain as well as, segmental strain at basal, mid and apical septum and RV free wall values, And also it was associated with a significant lower RV dimensions and higher function.

Keywords; Percutaneous Balloon Mitral Valvuloplasty – Right Ventricular - 2d Speckle Tracking Echocardiography.

Introduction

Mitral stenosis (MS) is the most frequent valvular complication of rheumatic fever. Even in industrialized countries, most cases are of rheumatic origin as other causes are rare. Given the decrease in the prevalence of rheumatic heart diseases, MS has become the least frequent single left-sided valve disease. However, it still accounts for 10% of left-sided valve diseases in Europe and it remains frequent in the developing countries(1).

Percutaneous balloon mitral valvuloplasty (BMV) was introduced in 1984 by Inoue et al. for the treatment of selected patients with mitral stenosis. BMV is a minimally invasive, nonsurgical procedure that has been established in several clinical studies to be a safe and effective therapeutic modality in selected patients with mitral stenosis (MS) and is equivalent to or even better than surgical commissurotomy(2). With successful BMV, there is generally a twofold increase in the mitral valve area and an associated dramatic fall in transmitral valve gradient, left atrial pressure, and pulmonary artery pressure. These hemodynamic benefits are associated with postprocedural improvement in the patients' symptoms and exercise (3).

Right ventricular (RV) function plays an important role in development of clinical symptoms and prognosis in patients with mitral stenosis (MS). This is primarily affected by hemodynamic effects on RV due to pulmonary hypertension(PH). RV dysfunction is not detected clinically until the development of clinical signs of systemic venous congestion RV functional assessment is difficult and not done routinely because of its complex anatomy and high load dependence(4).. Many indices have been developed for quantifying RV function. In common practice, clinicians largely rely on non-invasive imaging methods for assessment of the right ventricle function, thus two dimensional echocardiography is the mainstay for analysis the right ventricle of function, alternative techniques have been proposed, including tissue Doppler imaging techniques, three dimensional echocardiography, magnetic resonance imaging and speckle tracking echocardiography (5,6).

Speckle tracking allows the assessment of myocardial strain and strain rate.

Myocardial strain is a dimensionless index of tissue deformation expressed as a fraction or percent change(7). Myocardial lengthening gives a positive and shortening gives a negative strain value. Strain rate measures the local rate of deformation per unit time. Strain can be further subdivided into longitudinal, radial and circumferential strain. Longitudinal strain represents myocardial deformation directed from the base to the apex. Radial strain represents radially directed myocardial deformation. Two-dimensional strain and strain rate analyses are novel Doppler-independent techniques to obtain measurements of myocardial movement and deformation(8,9).

The aim of the present study was to evaluate right ventricular functions by speckle tracking-echocardiography in patients with severe rheumatic mitral stenosis before and after percutaneous mitral balloon valvuloplasty.

Study design and population:

This prospective study was conducted on 100 patients with severe rheumatic mitral stenosis admitted in Benha University and national heart institute underwent percutaneous mitral balloon valvuloplasty.

Inclusion criteria:

- Patients were undergoing percutaneous mitral balloon valvuloplasty due to severe rheumatic mitral stenosis

Exclusion criteria:

Patients have any of the followings:

1. Patients with severe tricuspid regurge.
2. Patients who show signs of concomitant aortic disease.
3. Patients with coronary artery disease.

4. Pericarditis.
5. Myocarditis.
6. COPD.
7. Patients with moderate to severe mitral regurge

All included patients were subjected to full history taking and complete clinical examination, and laboratory investigations as Complete blood picture (CBC), coagulation profile (INR, PTT, Prothrombin activity), Renal function test (serum creatinine, serum urea) and Virology profile (HCV, HBV, HIV). Standard 12-lead resting ECGs were recorded using a common ECG device (Hewlett Packard, Page-writer, USA) with a paper running speed of 25 mm/s. Resting Transthorathic Echocardiography was done with special stress on right ventricular function through the following parameters: Right ventricular index of myocardial performance (RIMP), Tricuspid annular plane systolic excursion (TAPSE), Right ventricular fractional area change (FAC), Right ventricular free wall thickness and tissue Doppler-derived tricuspid lateral annular systolic velocity (S').

Two dimensional (2-D) speckle tracking echocardiography (STE): Two-dimensional speckle tracking-derived right ventricle strain measured the global longitudinal strain, and segmental longitudinal strain at the apical, middle, and basal ventricular levels. The segmental longitudinal strain measures was included segmental longitudinal strain at the apex, middle, and basal ventricular levels of the right ventricular free wall and septal wall. Apical four-chamber view was used to measure the strain and strain rate of the right ventricular free wall and septal wall. Parameters are quantified in basal, mid, and apical segments of the septal and right ventricular free wall and measures was correlated with pulmonary artery systolic pressure.

An Official permission was obtained from Faculty of Medicine, Benha University. An official permission was obtained from National Heart Institute and Benha university hospital. Approval from ethical committee in the faculty of medicine (Institutional Research Board IRB).

Statistical Analysis:

Data management and statistical analysis were done using SPSS version 25. (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using Kolmogorov-Smirnov test and direct data visualization methods. According to normality testing, numerical data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages. Quantitative data were compared between study groups using independent t-test or Mann-Whitney U test for normally and non-normally distributed numerical variables, respectively. Categorical data were compared using the Chi-square or Fisher's exact test. All statistical tests were two-sided. P values less than 0.05 were considered significant.

Results

The mean age of the studied patients was 38 ± 10 years. There was a female predominance; about two-thirds (60.0%) were females. The mean BMI was 27 ± 5 . About one-third of the patients (36.0%) were hypertensive, and one-quarter (28.0%)

were diabetics. Also, one-quarter of the patients were smokers. In addition, dyslipidemia was reported in about one-quarter of the patients (28.0%) (*Table1*)

Table (1) General characteristics of the studied patients (n = 100)

<i>General characteristics</i>		
Age (years)	Mean \pm SD	38 \pm 10
Gender	Males n (%)	40 (40.0)
	Females n (%)	60 (60.0)
BMI	Mean \pm SD	27 \pm 5
Hypertension	n (%)	36 (36.0)
Diabetes mellitus	n (%)	28 (28.0)
Smoking	n (%)	28 (28.0)
Dyslipidemia	n (%)	28 (28.0)

BMI= Body mass index

❖ *Conventional 2D echo pre and post-BMV*

- The mitral valve area significantly increased from 0.87 before the procedure to 1.66 after the procedure (P-value < 0.001).
- LVEF significantly increased from 61 before the procedure to 65 after the procedure (P-value < 0.001).
- RV MPI significantly declined from 0.58 before the procedure to 0.55 after the procedure (P-value < 0.001).
- RV FAC significantly increased from 35.5 before the procedure to 46.5 after the procedure (P-value < 0.001).
- TAPSE significantly increased from 20 before the procedure to 22.5 after the procedure (P-value < 0.001).
- S wave velocity significantly increased from 11.5 before the procedure to 12.2 after the procedure (P-value < 0.001).

RV free wall thickness significantly declined from 27.9 before the procedure to 26.3 after the procedure (P-value < 0.001)

Table (2) Conventional 2D echo pre and post BMV

	Mean \pm SD	P-value
<i>Mitral valve area</i>		
Pre	0.87 \pm 0.05	< 0.001
Post	1.66 \pm 0.14	
<i>LVEF</i>		
Pre	61 \pm 5	< 0.001
Post	65 \pm 4	
<i>RV MPI</i>		
Pre	0.58 \pm 0.08	< 0.001
Post	0.55 \pm 0.09	
<i>RV FAC</i>		
Pre	35.5 \pm 10.4	< 0.001
Post	46.5 \pm 7.1	
<i>TAPSE</i>		
Pre	20 \pm 2.9	< 0.001
Post	22.2 \pm 3	

<i>S` wave velocity</i>		
Pre	11.5 ±1.3	< 0.001
Post	12.2 ±1.2	
<i>RV free wall thickness</i>		
Pre	27.9 ±2.7	< 0.001
Post	26.3 ±2	

RV= right ventricular, LVEF = left ventricular ejection fraction, RV MPI = right ventricular myocardial performance index, TAPSE = tricuspid annular plane systolic excursion, S' = peak systolic velocity at lateral tricuspid annulus, FAC = fractional area change.

❖ *The longitudinal strain of RV pre and post-BMV*

- At the basal septum, the strain significantly increased from -12 before the procedure to -14.4 after the procedure (P-value < 0.001).
- At the mid septum, the strain significantly increased from -9.6 before the procedure to -13.7 after the procedure (P-value < 0.001).
- At the apical septum, the strain significantly increased from -13.2 before the procedure to -15.9 after the procedure (P-value < 0.001).
- At basal RV free wall, the strain significantly increased from -23.1 before the procedure to -26.8 after the procedure (P-value < 0.001).
- At the mid-RV free wall, the strain significantly increased from -17.2 before the procedure to -21.5 after the procedure (P-value < 0.001).
- At the apical RV free wall, the strain significantly increased from -16 before the procedure to -19.3 after the procedure (P-value < 0.001).

Global RV strain significantly increased from -9.3 before the procedure to -11 after the procedure (P-value < 0.001)

Table (3) Longitudinal strain of RV pre AND post-BMV

	Mean ±SD	P-value
<i>Basal septum</i>		
Pre	-12 ±2.5	< 0.001
Post	-14.4 ±3.3	
<i>Mid Septum</i>		
Pre	-9.6 ±3.2	< 0.001
Post	-13.7 ±2.8	
<i>Apical septum</i>		
Pre	-13.2 ±2.9	< 0.001
Post	-15.9 ±3.6	
<i>Basal RV free wall</i>		
Pre	-23.1 ±9.3	< 0.001
Post	-26.8 ±7.9	
<i>Mid RV free wall</i>		
Pre	-17.2 ±6.9	< 0.001
Post	-21.5 ±6.1	
<i>Apical RV free wall</i>		
Pre	-16 ±5.6	< 0.001
Post	-19.3 ±6.5	
<i>Global RV</i>		

Pre	-9.3 ±2.5	< 0.001
Post	-11 ±2.8	

RV= right ventricular

❖ *The longitudinal strain rate of RV pre and post-BMV*

- At the basal septum, the strain rate significantly increased from 1.09 before the procedure to 1.27 after the procedure (P-value < 0.001).
- At mid septum, the strain rate significantly declined from 1.09 before the procedure to 0.94 after the procedure (P-value < 0.001).
- At the apical septum, the strain rate significantly increased from 0.85 before the procedure to 0.9 after the procedure (P-value < 0.001).
- At basal RV free wall, the strain rate significantly increased from 2.56 before the procedure to 3.04 after the procedure (P-value < 0.001).
- At the mid-RV free wall, the strain rate significantly declined from 3.2 before the procedure to 2.56 after the procedure (P-value < 0.001).

At the apical RV free wall, no significant difference was noted in the strain rate (P-value = -0.434)

Table (4) Longitudinal strain rate of RV pre and post-BMV

	Mean \pm SD	P-value
<i>Basal septum</i>		
Pre	1.09 \pm 0.4	< 0.001
Post	1.27 \pm 0.43	
<i>Mid Septum</i>		
Pre	1.09 \pm 0.64	< 0.001
Post	0.94 \pm 0.33	
<i>Apical Septum</i>		
Pre	0.85 \pm 0.24	< 0.001
Post	0.9 \pm 0.18	
<i>Basal RV free</i>		
Pre	2.56 \pm 1	< 0.001
Post	3.04 \pm 1.19	
<i>Mid RV free wall</i>		
Pre	3.2 \pm 1.7	< 0.001
Post	2.56 \pm 0.92	
<i>Apical RV free wall</i>		
Pre	1.5 \pm 0.8	0.434
Post	1.48 \pm 0.54	

RV= right ventricular

Paired t-test was used

Discussion

The mitral valve (MV) is the most commonly and severely affected (65%–70% of patients) by rheumatic process by stenosis and/or regurgitation. Right ventricular (RV) function plays an important role in development of clinical symptoms and prognosis in patients with MS(10), RV functional assessment is difficult and not done routinely because of its complex anatomy and high load dependence. Many indices have been developed for quantifying RV function, among which strain and strain rate are relatively new. Myocardial strain is a measure of tissue deformation(11).

Our study included 100 patients (40 males and 60 females) with severe mitral stenosis. The proportion of males and females in this study (40% males, 60% females). Their mean age was 38 ± 10 years. Regarding risk factors, 36% of patients were known to be hypertensive, 25% were dyslipidemic, while 26% were smokers and 28% were known to be diabetic.

In our study, the mean of strain values pre PBMV was -5.52. There was statistically significant difference between the mean of strain values at pre PBMV and 3rd month post PBMV ($p=0.967$). The mean of strain rate values pre PBMV was -0.01. There was statistically non significant difference between the mean of strain rate values at pre PBMV and 3rd month post PBMV ($p=0.407$).

Our results agreed with the study of **Roushdy et al.**, as they reported that PBMV resulted in significant improvement in LV and RV GLS within 24 hrs post-PBMV compared with baseline values ($p=0.0001$ and 0.0002 , respectively), an improvement which was maintained after 3 months. There was significant positive correlation between both LV and RV GLS at baseline and mitral valve mean pressure gradient and RV systolic pressure and significant inverse correlation between LV GLS and MVA

Similarly, **Tanboga et al.**, (12) revealed that their study included 59 patients with isolated MS (mild and moderate) and 31 healthy control subjects. RV strain (23.5 ± 7.2 vs. 18.63 ± 6.3 , $p=0.001$) and RV strain rate (1.72 ± 0.54 vs. 1.37 ± 0.66 , $p=0.01$) measurements were significantly lower in patients with MS than the control group. However, RV strain and strain rate measurements were comparable between MS subgroups. Correlation analysis revealed that there was poor correlation between right ventricular longitudinal strain/ longitudinal strain rate (RV-LS/LSr) and mean-maximum gradients and echo score but moderate correlation between RV-LS and RV-Sr in systolic pulmonary artery pressure and planimetric mitral valve area.

Khanna et al also had similar results in their study, As they evaluated 80 patients pre- and post-PMC, they reported a significant improvement in the strain measures of the base and mid segments of the RV free wall (longitudinal strain of the basal free wall = $-24.4 \pm 6.1\%$ vs $-27.7 \pm 5.8\%$; $P < .001$ and longitudinal strain of the mid free wall = $-25.6 \pm 5.5\%$ vs $-28.5 \pm 5.1\%$; $P < .001$). Khanna et al measured strain parameters by tissue Doppler imaging, which was somehow a less precise method because of its angle dependency and lower signal-to-noise ratio.

Our results were in line with the study of **Nagel et al.**, which showed that RV ejection fraction was related to mean PA pressure, suggesting RV afterload to be the culprit for RV dysfunction rather than intrinsic contractile dysfunction. They also found an inverse correlation between PA systolic pressure and peak systolic global RV strain, segmental strain at basal, mid, apical septum and the basal RV free wall.

Also, **Weidemann et al.**, (13) revealed that strain affected by loading conditions, whereas the strain rate more closely reflects contractility and was load independent. RV free wall strain did not show immediate improvement, And also showed improvement in long-term follow up.

In our study, Right ventricular outflow tract-Fractional shortening (RVOT-FS) showed a statistically significant increase from 32.9 ± 4.06 pre PBMV to 50.5 ± 5.76 at the 3rd month ($p_2 < 0.001$). Tricuspid annular plane systolic excursion (TAPSE) showed a

statistically significant increase from 19.1 ± 4.88 mm pre PBMV to 24.3 ± 4.99 mm at the 3rd month ($p_2 < 0.001$). Also, TAPSE showed a statistically significant increase from pre PBMV to the 3rd month ($p_3 < 0.001$).

Our results agreed with a study of **Mahfouz et al., (14)** who conducted a prospective study included 45 patients with MS candidate for PBMV (age 38 ± 19 years, 27 were females). TAPSE showed a statistically significant increase from 12.35 ± 3.2 mm pre PBMV to 27.1 ± 4.6 mm at the 1st week ($p < 0.001$).

Our results were against the study of **Morttada et al., (15)** as they evaluated the impact of successful PBMV on RV function in 30 patients who underwent PBMV for rheumatic MS. Results revealed a significant drop in TAPSE before and 24 h after (Mean 22.320 ± 4.005 , $p = 0.008$) and before and 3 months after (Mean 20.657 ± 2.878 , $p = 0.001$). There was no significant change between 24h and 3months after the procedure (Mean 20.167 ± 2.493 , $P = 0.220$).

Furthermore, **Kumar et al.,** revealed that TAPSE showed a significant rise from 21.12 ± 5.00 mm pre PBMV to 23.10 ± 4.03 mm post PBMV ($p = 0.031$).

While, in the study of **Saroumadi et al.,** Thirty three consecutive patients (70% women; age 31 ± 8 years; range 19-45) with moderate to severe mitral stenosis (mitral valve area $< 1.5 \text{ cm}^2$) in sinus rhythm who underwent successful BMV were include prospectively. Echocardiographic parameters of RV function were determined before BMV, and one month after BMV and included pulsed wave TDI (S velocity, isovolumic relaxation time (IVRT), Tei index), tricuspid annular plane systolic excursion (TAPSE), RV fractional area change (RVFAC). Mitral valve area increased from 0.88 ± 0.16 to $1.55 \pm 0.26 \text{ cm}^2$ ($p < 0.0001$). There was a significant increase in TAPSE ($p = 0.01$ after BMV), There was no significant change with regard to TDI S velocity and 2D.

The difference between these studies and ours may be attributed to different inclusion criteria, different sample size and different severity of cases.

Conclusion

RV systolic function is impaired in patients with severe MS and can be assessed by global and segmental RV strain before the appearance of clinical signs of systemic venous congestion, After Percutaneous Balloon Mitral Valvuloplasty (PBMV), it was associated with significant rise in the Global RV systolic strain as well as, segmental strain at basal, mid and apical septum and RV free wall values, And also it was associated with a significant lower RV dimensions and higher function.

Limitations

Small sample size- Limited duration of the study

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Nil

Conflicts of interest

There are no conflicts of interest.

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