

# Impact of Percutaneous Balloon Mitral Valvotomy on Echocardiographic Parameters in Patients with Mitral Stenosis

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## Abstract

**Background:** Mitral stenosis remains a major cardiovascular burden in underdeveloped nations, owing mostly to rheumatic heart disease. Percutaneous balloon mitral valvotomy (PBMV) has become the recommended treatment for symptomatic severe mitral stenosis with normal valve shape. The purpose of this study was to evaluate the impact of percutaneous balloon mitral valvotomy on conventional echocardiographic indices and left atrial strain parameters in patients with mitral stenosis.

**Methods:** This prospective observational study was conducted in the Department of Cardiology at the National Institute of Cardiovascular Diseases, Dhaka, Bangladesh, from January to July 2021, on 24 consecutive patients with severe rheumatic mitral stenosis undergoing PBMV at a tertiary cardiac center. Comprehensive transthoracic echocardiography, including conventional parameters and two-dimensional speckle-tracking strain analysis, was performed 24 hours before and 48 hours after the procedure. Data were entered and analyzed on SPSS version 26.

**Results:** PBMV significantly improved mitral valve area from  $0.77 \pm 0.20$  cm<sup>2</sup> to  $1.69 \pm 0.41$  cm<sup>2</sup> ( $P < 0.0001$ ). The mean transmittal pressure gradient fell from  $10.75 \pm 3.15$  mmHg to  $7.04 \pm 4.53$  mmHg ( $P < 0.0001$ ), while pulmonary artery systolic pressure declined from  $33.50 \pm 17.41$  mmHg to  $25.63 \pm 13.83$  mmHg ( $P = 0.003$ ). The global left atrial strain significantly improved from  $11.49 \pm 4.65\%$  to  $17.13 \pm 5.30\%$  ( $P < 0.0001$ ). Significant associations were seen between changes in mitral valve area and improvements in mean gradient ( $r = -0.62$ ,  $P = 0.001$ ), peak gradient ( $r = -0.58$ ,  $P = 0.003$ ), pulmonary pressure ( $r = -0.51$ ,  $P = 0.010$ ), and global left atrial strain ( $r = +0.66$ ,  $P < 0.001$ ).

**Conclusion:** PBMV causes immediate and considerable improvements in traditional hemodynamic measures as well as left atrial mechanical function as measured by global longitudinal strain. The substantial association between mitral valve area enlargement and strain improvement suggests that left atrial strain could be a useful supplementary marker of effective intervention and a possible predictor of positive outcomes.

**Keywords:** Mitral stenosis, percutaneous balloon mitral valvotomy, left atrial strain, echocardiography

## Introduction

Mitral stenosis (MS) remains a significant health burden in developing nations, mainly due to acute rheumatic fever and chronic rheumatic heart

disease. Although the incidence of MS has been decreasing in industrialized nations, the disease remains highly prevalent in South Asian, Sub-Saharan African, and other resource-poor nations with poor prophylactic measures for rheumatic

fever.<sup>[1]</sup> The pathophysiological effects of MS include an increase in left atrial pressure, pulmonary venous congestion, pulmonary hypertension, and right heart failure, which may cause considerable morbidity and mortality if untreated.<sup>[2]</sup> Since the advent of PBMV in the 1980s, it has transformed the management of symptomatic severe MS with favorable valve morphology. Numerous studies have confirmed PBMV as the treatment of choice for MS with comparable long-term results to surgical commissurotomy, with the advantages of lower procedure-related complications, hospital stay, and cost.<sup>[3,4]</sup> The mechanical intervention of PBMV involves the splitting of the mitral valve leaflets, thereby relieving the obstruction of the valve. The procedure improves the hemodynamic function of the mitral valve, as evidenced by an increase in the mitral valve area, reduction in transvalvular gradients, and decrease in left atrial and pulmonary artery pressures.<sup>[5]</sup> Transthoracic echocardiography plays an essential role as a cornerstone for the diagnosis, risk stratification, and post-procedure assessment of MS patients undergoing PBMV.<sup>[6]</sup> Routine echocardiographic parameters such as MVA using planimetry, assessment of transmitral gradients using continuous-wave Doppler echocardiography, and estimation of pulmonary artery systolic pressure are essential in predicting procedural outcomes.<sup>[7]</sup> These routine echocardiographic parameters mainly focus on the mechanical obstruction and its hemodynamic consequences, but do not address the functional adaptations of the cardiac chambers due to chronic pressure overload. Two-dimensional speckle tracking echocardiography (2D STE) has also emerged as an important technique for the assessment of myocardial deformation and atrial function.<sup>[8]</sup> Left atrial global longitudinal strain (LA GLS), measured using 2D STE, is a quantitative measure of the reservoir function of the left atrium. It has also been correlated with atrial fibrosis, filling pressures, and adverse cardiovascular outcomes in various clinical conditions.<sup>[9]</sup> In the setting of MS, the LA is subjected to considerable remodeling changes due to chronic pressure and volume overload, which manifests

as chamber dilatation, myocardial fibrosis, and impaired contractile function.<sup>[10]</sup> There is emerging evidence of the potential of the LA strain for the assessment of subclinical atrial dysfunction and prediction of outcomes. Although several studies have demonstrated the beneficial effects of PBMV on conventional echocardiographic parameters, a comprehensive evaluation of the effects of PBMV on advanced strain echocardiography parameters in the early period after the procedure has not been well studied, especially in resource-constrained countries where rheumatic MS is common.<sup>[11]</sup> The early effects of PBMV on conventional parameters and atrial mechanical functions may help us understand the mechanisms of the beneficial effects of the procedure and may also help us predict the likelihood of a successful outcome. This study was designed to evaluate the effects of PBMV on conventional echocardiographic parameters and left atrial global longitudinal strain in patients with rheumatic mitral stenosis, and also the correlations between the parameters.

## Methods

From January to July 2021, this prospective observational study was carried out in the Department of Cardiology at the National Institute of Cardiovascular Diseases in Dhaka, Bangladesh. The institutional Ethical Review Committee accepted the study protocol based on the Declaration of Helsinki. Before participation, each participant or their legal guardian provided written informed consent. The confidentiality of patient information was strictly preserved, and participants were free to resign from the study at any time without affecting their clinical care. All consecutive patients with chronic rheumatic heart disease and severe mitral stenosis who were scheduled to undergo percutaneous balloon mitral valvulotomy during the index hospitalization were screened, and 24 patients who met the inclusion criteria were recruited consecutively. The inclusion criteria were patients between 15 and 45 years of age, symptomatic severe mitral stenosis with a valve area of less than 1.5 cm<sup>2</sup>,

favorable valve morphology defined as a Wilkins score of 10 or less, and suitability for PBMV as judged by the treating cardiologist. Exclusion criteria were mild mitral stenosis, unfavorable valve morphology defined as a Wilkins score of more than 10, the presence of commissural calcification or left atrial thrombus, moderate to severe valvular disease other than mitral stenosis, coronary artery disease, left ventricular ejection fraction of less than 50%, signs of right-sided heart failure, or atrioventricular conduction abnormalities. Routine investigations, 12-lead electrocardiography, and chest X-ray were carried out on all patients. Detailed transthoracic echocardiography was performed using a commercially available ultrasound system by a single experienced operator, unaware of the follow-up data. The mitral valve area was measured using planimetry, the morphology of the valve using the Wilkins score, the left atrium diameter, left ventricle dimensions, and the left ventricle ejection fraction using Simpson's formula. The peak and mean gradients, as well as the pulmonary artery systolic pressure, were measured using Doppler echocardiography. Two-dimensional speckle-tracking echocardiography from optimal apical windows was used to measure the left atrium global longitudinal strain. All echocardiographic parameters were performed one day before PBMV and 24 to 48 hours after the procedure. The data were analyzed using IBM SPSS version 26.0. For the results, the numerical variables were described using the mean and standard deviation, whereas the categorical variables were described in terms of frequencies and percentages. To compare the pre- and post-procedure results, a paired *t*-test was used, and correlations were determined using Pearson's coefficient, where  $P \leq 0.05$  was considered statistically significant.

## Results

The demographic distribution of the study population is shown in Table 1. The age group with the highest percentage of patients (45.8%) was 31–40 years old, followed by 41–50 years old

(29.2%) and 21–30 years old (25%). Males made up 29.2% of the cohort, with women making up 70.8% of the total [Table 1].

The clinical symptom profile of the recruited individuals is shown in Table 2. All 24 patients (100%) had breathlessness, which is a hallmark of mitral stenosis. Most had paroxysmal nocturnal dyspnea (83.3%) and palpitations (87.5%). 37.5% of patients reported having a cough or chest pain, while 25% reported having orthopnea. The rheumatic etiology was confirmed in 87.5% of cases with a history of rheumatic fever. Remarkably, just 33.3% had been prophylactically treated for rheumatic fever [Table 2].

The baseline general examination results are summarized in Table 3. With mean systolic and diastolic blood pressure readings of  $127.14 \pm 15.75$  mmHg and  $80.7 \pm 9.16$  mmHg, respectively, and a mean pulse rate of  $80.46 \pm 9.08$  beats per

**Table 1:** Distribution of demographic profiles ( $n = 24$ )

Variables	<i>n</i>	%
<b>Age group</b>	–	–
21–30 years	6	25.0
31–40 years	11	45.8
41–50 years	7	29.2
<b>Gender</b>	–	–
Female	17	70.8
Male	7	29.2

**Table 2:** Distribution of clinical features

Symptoms	<i>n</i>	%
Breathlessness	24	100
Palpitation	21	87.5
Paroxysmal nocturnal dyspnea	20	83.3
Chest pain	9	37.5
Cough	9	37.5
Orthopnea	6	25
History of rheumatic fever	21	87.5
History of rheumatic fever prophylaxis	8	33.3

minute, the patients were hemodynamically stable at baseline. The average jugular vein pressure was  $8.94 \pm 0.30$  cm, which is within normal bounds [Table 3].

Table 4 depicts the changes in the routine echocardiographic parameters after PBMV. The mitral valve area improved dramatically from  $0.77 \pm 0.20$  cm<sup>2</sup> before the procedure to  $1.69 \pm 0.41$  cm<sup>2</sup> after the procedure, with a significant increase of  $0.92 \pm 0.38$  cm<sup>2</sup> ( $P < 0.0001$ ), confirming the mechanical relief of mitral stenosis. The left atrium diameter did not change significantly, with a slight increase from  $44.61 \pm 4.26$  mm before the procedure to  $44.95 \pm 4.11$  mm after the procedure ( $P = 0.679$ ). The left ventricular end-diastolic dimension increased significantly from  $40.96 \pm 5.54$  mm before the procedure to  $43.53 \pm 5.66$  mm after the procedure ( $P = 0.028$ ), possibly due to the immediate improvement in the left ventricular function [Table 4].

**Table 3:** General examination findings

Variables	Mean $\pm$ SD
Pulse (bpm)	$80.46 \pm 9.08$
Systolic blood pressure (mmHg)	$127.14 \pm 15.75$
Diastolic blood pressure (mmHg)	$80.7 \pm 9.16$
Jugular venous pressure (cm)	$8.94 \pm 0.30$

The Doppler-derived parameters are shown in Table 5. The peak gradient decreased significantly from  $18.04 \pm 5.23$  to  $12.42 \pm 5.87$  mmHg ( $P < 0.0001$ ), and the mean gradient decreased from  $10.75 \pm 3.15$  to  $7.04 \pm 4.53$  mmHg ( $P < 0.0001$ ). The pulmonary artery systolic pressure decreased significantly from  $33.50 \pm 17.41$  to  $25.63 \pm 13.83$  mmHg ( $P = 0.003$ ), which shows the relief [Table 5].

Table 6 shows the marked improvement in left atrial mechanical function following PBMV. Global left atrial longitudinal strain was found to increase significantly from  $11.49 \pm 4.65\%$  to  $17.13 \pm 5.30\%$  ( $P < 0.0001$ ), with a mean improvement of approximately 49% [Table 6].

Correlation analyses between changes in mitral valve area and changes in other hemodynamic and functional parameters are shown in Table 7. Significant negative correlations were found between changes in mitral valve area and reductions in mean transmitral gradient ( $r = -0.62$ ,  $P = 0.001$ ) and peak gradient ( $r = -0.58$ ,  $P = 0.003$ ). In addition, a moderate negative correlation was also found between changes in mitral valve area and reductions in pulmonary artery pressure ( $r = -0.51$ ,  $P = 0.010$ ). Most notably, a significant positive correlation was noted between changes in mitral valve area and improvements in global

**Table 4:** Comparison of conventional echocardiographic parameters before and after PBMV

Variables	Before PBMV	After PBMV	Mean change	t-value	P-value
LA diameter (mm)	$44.61 \pm 4.26$	$44.95 \pm 4.11$	$+0.34 \pm 1.21$	-0.42	0.679
LVEDd (mm)	$40.96 \pm 5.54$	$43.53 \pm 5.66$	$+2.57 \pm 4.61$	-2.32	0.028
LVESd (mm)	$26.94 \pm 5.81$	$28.42 \pm 5.01$	$+1.48 \pm 4.32$	-1.16	0.254
LVEF (%)	$62.33 \pm 8.65$	$62.90 \pm 9.68$	$+0.57 \pm 3.84$	-0.37	0.720
MVA (cm <sup>2</sup> )	$0.77 \pm 0.20$	$1.69 \pm 0.41$	$+0.92 \pm 0.38$	-11.75	< 0.0001

**Table 5:** Comparison of doppler echocardiographic findings before and after PBMV

Variables	Before PBMV	After PBMV	P-value
Peak pressure gradient across mitral valve (mmHg)	$18.04 \pm 5.23$	$12.42 \pm 5.87$	< 0.0001
Mean pressure gradient across the mitral valve (mmHg)	$10.75 \pm 3.15$	$7.04 \pm 4.53$	< 0.0001
Pulmonary artery systolic pressure (mmHg)	$33.50 \pm 17.41$	$25.63 \pm 13.83$	0.003

left atrial strain ( $r = +0.66, P < 0.001$ ), indicating a correlation between procedural success and improvement in atrial function [Table 7].

## Discussion

This prospective observational study was undertaken to assess the immediate effects of PBMV on conventional echocardiographic parameters and advanced left atrial strain imaging in patients with rheumatic mitral stenosis. Our results show that PBMV not only improves the expected hemodynamic parameters but also significantly enhances left atrial mechanical function as assessed by two-dimensional speckle-tracking strain echocardiography. This is an important contribution to the expanding literature supporting the utility of advanced atrial functional imaging in the routine assessment of PBMV. The study group had a mean age of approximately 35 years with a female predominance of 70.8%, which is similar to the known epidemiology of rheumatic mitral stenosis shown by Zühlke et al.<sup>[12]</sup> The clinical presentation of the group was typical, with universal breathlessness, palpitations, paroxysmal nocturnal dyspnea, and a known history of rheumatic fever. However, only one-third of the group had adequate prophylaxis for rheumatic fever, emphasizing the need to improve secondary prophylaxis measures in the developing world.<sup>[13]</sup> The demographic

profile of the study group is similar to the large South Asian registries of PBMV cases.<sup>[14]</sup> The conventional echocardiographic results of this study reinforce the established efficacy of PBMV. The substantial rise in mitral valve area from 0.77 cm<sup>2</sup> to 1.69 cm<sup>2</sup> indicates good procedural success and compares favorably with results by Fawzy et al.<sup>[15]</sup> The results of the majority of the patients demonstrate procedural success according to established criteria for optimal PBMV as indicated by a post-procedure mitral valve area of more than 1.5 cm<sup>2</sup> in the absence of significant mitral regurgitation.<sup>[16]</sup> The reduction in peak and mean transmit pressure gradients correlates well with the efficacy of PBMV in alleviating valvular obstruction, as supported by the inverse relationship between mitral valve area and transvalvular gradients as predicted by the Gorlin equation.<sup>[17]</sup> A clinically significant finding of the study was the reduction in pulmonary artery systolic pressure after PBMV. The pulmonary hypertension that occurs in mitral stenosis is a result of increased left atrial pressure over a long period of time, leading to pulmonary vasoconstriction and eventual vascular remodeling in the pulmonary vessels.<sup>[18]</sup> The reduction in pulmonary artery pressure seen in our study indicates that the pulmonary hypertension that was seen in the patients before the procedure was passive and that the pulmonary artery pressure returned to normal after the PBMV. This has prognostic implications

**Table 6:** Comparison of global left atrial strain before and after PBMV ( $n = 24$ )

Variable	Before PBMV (mean ± SD)	After PBMV (mean ± SD)	P-value
Global left atrial strain (%)	11.49 ± 4.65	17.13 ± 5.30	< 0.0001

**Table 7:** Correlation between change in mitral valve area and changes in hemodynamic and functional parameters after PBMV

Correlated variables	Correlation coefficient ( $r$ )	P-value
Mitral valve area vs Mean mitral pressure gradient	-0.62	0.001
Mitral valve area vs Peak mitral pressure gradient	-0.58	0.003
Mitral valve area vs Pulmonary artery pressure	-0.51	0.010
Mitral valve area vs Global left atrial strain	+ 0.66	< 0.001

because pulmonary hypertension that persists after PBMV is associated with poor outcomes.<sup>[19]</sup> The positive correlation between the improvement in the mitral valve area and the reduction in the pulmonary artery pressure also indicates a direct relationship between the two. The increase in left ventricular end-diastolic dimension after PBMV represents another important hemodynamic effect. In severe mitral stenosis, the left ventricle is chronically underfilled, resulting in decreased left ventricular chamber size.<sup>[20]</sup> The improvement in transmitral flow after PBMV will result in improved left ventricular filling and normalization of left ventricular chamber geometry, explaining the increase in LVEDd without compromising left ventricular systolic function. Similar results have been observed in a study by Fawzy et al. and are usually associated with improved cardiac output and functional capacity.<sup>[21]</sup> The most novel aspect of this study is the evaluation of left atrial mechanical function using two-dimensional speckle-tracking echocardiography. Global left atrial longitudinal strain improved after PBMV, suggesting that left atrial dysfunction in patients with mitral stenosis is not only the result of irreversible structural changes, as indicated by left atrial enlargement but also involves reversible functional changes due to pressure overload.<sup>[22]</sup> Singh et al. have demonstrated the prognostic value of left atrial strain in different cardiovascular conditions.<sup>[23]</sup> The results of this study have extended the prognostic value of left atrial strain to patients with rheumatic mitral stenosis undergoing PBMV. Significantly, the strong positive correlation between improvement in mitral valve area and improvement in left atrial strain suggests that the more successful the procedure, the better the recovery of the mechanical function of the atrium. This supports the potential value of left atrial strain as a measure of procedural success that reflects both the improvement in the patient's hemodynamics and the functional recovery of the atrium itself.<sup>[24]</sup> These findings support the potential value of further investigation into the role of left atrial strain as a measure of the success of the PBMV procedure and as a potential predictor of long-term outcome.

## Limitations of the Study

The relatively small sample size and single-center design may limit the generalizability of findings. Long-term follow-up data evaluating the prognostic significance of post-procedural strain parameters were not available in this short-term observational study.

## Conclusion

Percutaneous balloon mitral valvotomy has been shown to result in significant improvements in conventional parameters and left atrial mechanical function using global longitudinal strain. The strong correlation between the increase in mitral valve area and left atrial strain suggests that left atrial strain may be a useful additional tool for the assessment of the result of the procedure and may have the potential for predicting long-term results. This supports the utility of advanced strain echocardiography in the comprehensive echocardiographic assessment of the patient.

## Recommendations

Future multicenter studies with larger sample sizes and extended follow-up should evaluate the prognostic value of left atrial strain for predicting long-term clinical outcomes, including recurrent symptoms, atrial fibrillation, and the need for repeat intervention. Investigation of serial strain measurements may help identify the optimal timing for intervention in asymptomatic patients with progressive mitral stenosis.

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