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# Long-term effects of percutaneous balloon mitral valvuloplasty on left atrial function

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**ABSTRACT**— Balloon mitral valvuloplasty (BMV) has been the procedure of choice for patients with significant mitral stenosis. It was suggested that successful BMV reduces the size of the left atrium and improves left atrial function in patients with MS. The purpose of this study was to evaluate long-term effects of BMV on left atrial function. The study included 70 patients with mitral stenosis who underwent BMV 1 year or more before and were coming for routine follow up echocardiography post BMV at Ain-Shams university hospital. Catheterization data and echocardiographic data of the patients before and immediately after BMV were retrospectively collected and compared to the echocardiographic data obtained at the follow up, one year or more after BMV. The mean age of this study group at time of procedure was 34.7 ± 12.08 years. The majority of the study were females representing 75.71% of the cases. BMV resulted in an immediate significant improvement of mitral valve area, mean transmitral pressure gradient and right ventricular systolic pressure with an immediate marked improvement in all LA diameters, areas, volumes and LA function. At the long-term follow up, the results have shown a significant improvement of LA function index (LAFI), LA end systolic volume (LAESV) with the indexed volume (LAESVI) and LA transverse diameter, in comparison to immediately post BMV results. BMV has good immediate and long-term results leading to a significant improvement of LA volumes and function.

**KEYWORDS:** Balloon valvuloplasty, Mitral valve stenosis, Left atrial function.

## 1. INTRODUCTION

Normal left atrial function is pivotal for maintaining optimal overall cardiac function as it plays different roles throughout the cardiac cycle. Normally, the left atrium (LA) has 3 phasic functions as it acts as a reservoir, conduit and pump booster during ventricular systole, early ventricular diastole and late diastole, respectively [1]. In mitral stenosis (MS), LA function may be disrupted because of increased LA afterload which leads to LA dilatation and fibrosis of the atrial wall [2] and, consequently, an impairment in LA contractile function.

Though MS has shown to affect all three phasic functions of LA, only reservoir function appears to improve after BMV, both early and on the 1 year follow-up intervals [3], [4].

BMV is considered the procedure of choice for patients with moderate or severe mitral stenosis [5]. Percutaneous balloon mitral valvuloplasty (PBMV) has shown excellent immediate and midterm results for many patients and substituted surgical mitral commissurotomy as the preferred procedure for patients with significant MS [6].

While there are many previous studies about immediate results post-BMV and fewer about mid-term or long-term results, studies reporting the long-term results are limited. The purpose of this study is to show long-term effects of BMV on LA function using LA function index (LAFI) which is a formula that integrates LA dimensions, LA reservoir function and cardiac output [7].

## 2. Methods

This was a retrospective cross-sectional study that included 70 patients who were referred for follow up echocardiography at Ain-Shams university hospitals post-BMV and had the following criteria:

Inclusion criteria
-Adults who had significant MS and who underwent BMV at least one year before.

Exclusion criteria
-Any patient with another significant valvular lesion other than valvular mitral stenosis.
-Patients with pericardial diseases.
-Patients with serious respiratory distress.
The data of all patients were collected and a master table was done to include the following:
1- Personal and anthropometric data including age of the patients, their sex and body surface area.
2- Pre-BMV and immediately post-BMV echocardiographic data including; mitral valve area (MVA), mean transmitral pressure gradient (MPG), Wilkins score, mitral regurgitation degree (MR), right ventricular systolic pressure (RVSP), LA dimensions and function.
3- Catheterization data including pre and post BMV, mean transmitral pressure gradient, left atrial pressure (LAP) and RVSP.
4-12 lead surface electrocardiogram to document the presence of normal sinus rhythm or atrial fibrillation (AF).

### *2.1 Follow up Echocardiogram*

All patients were studied by expert cardiologist at time of presentation.
Standard 2D and M-mode images in apical four-chamber (A4C) and left parasternal long-axis (PLAX) views were obtained according to American society of echocardiography [8] in order to:
a-Measure LA antero-posterior (LA-AP) diameter using M-mode in left PLAX by planimetry guided measurement.
b-Measure LA major (supero-inferior) and minor (septo-lateral) lengths in A4C view by planimetry guided measurement.
c-Measurement of maximal and minimal LA volumes (LAVmax and LAVmin) as well as maximal and minimal LA areas during ventricular systole and diastole respectively using Simpson’s method in A4C view [9]. Figure (1)

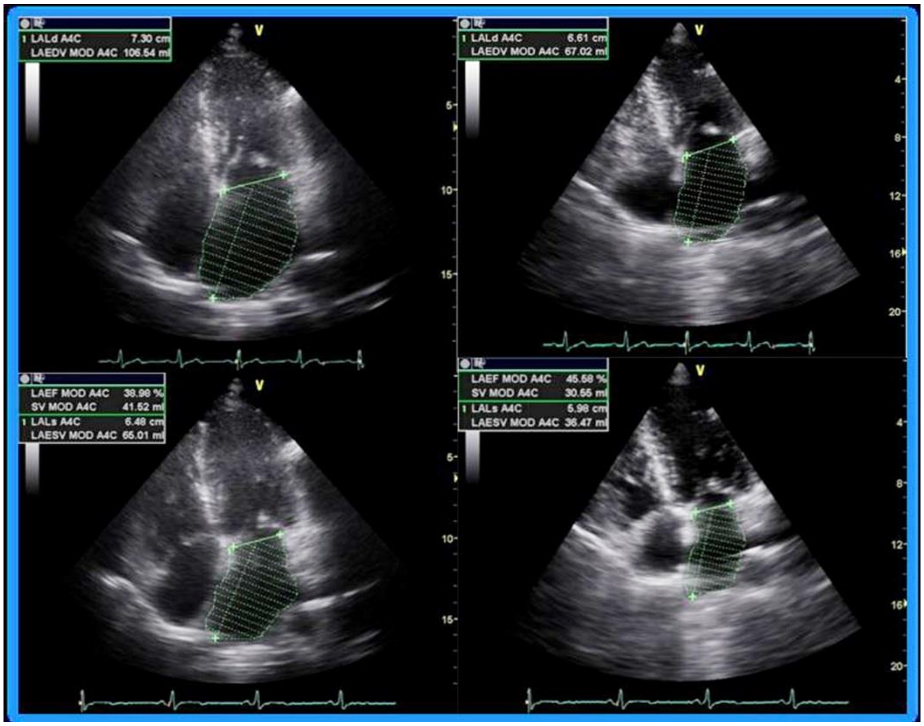


**Figure (1)** shows significant improvement of LA volumes post BMV:

Upper left image shows: LA maximal volume in A4C view pre BMV, upper right image shows: LA maximal volume in A4C view at follow up (after 1 year).
Lower left image shows: LA minimal volume in A4C view pre BMV, lower right image shows: LA minimal volume in A4C view at follow up (after 1 year).

-Left atrial total emptying fraction (LATEF) was then measured as (LAVmax-LAVmin)/ LAVmax X 100
-Indexed left atrial volumes (LAESVI: Left Atrial End Systolic Volume Indexed and LAEDVI: Left Atrial End Diastolic Volume Indexed) as well as indexed areas (LAESAI: Left Atrial End Systolic Area Indexed and LAEDAI: Left Atrial End Diastolic Indexed) were then calculated by dividing the respective values by body surface area.
-Velocity time integral across left ventricular outflow tract (LVOT VTI) was calculated using apical 5 chamber view by placing the pulsed wave doppler below the aortic valve and then the velocity was recorded (cm/s).
-The LA function index (LAFI) was then calculated using the following formula [10]:

$$LAFI = \frac{LATEF \times LVOT\text{-}VTI}{LAESVI}$$

LATEF = LAESV−LAEDV / LAESV × 100
LAESV= maximal LA volume at the end of ventricular systole (ml).
LAEDV= minimal LA volume at the end of ventricular diastole (ml).
Evaluation of mitral valve (MV) was done from the parasternal long-axis and short-axis views as well as A4C view. Assessment of MS degree was done by measurement of velocity-derived mean diastolic trans-mitral pressure gradient, measurement of planimetry-derived MVA in left parasternal short axis view and measurement of MVA by PHT. Figure (2)

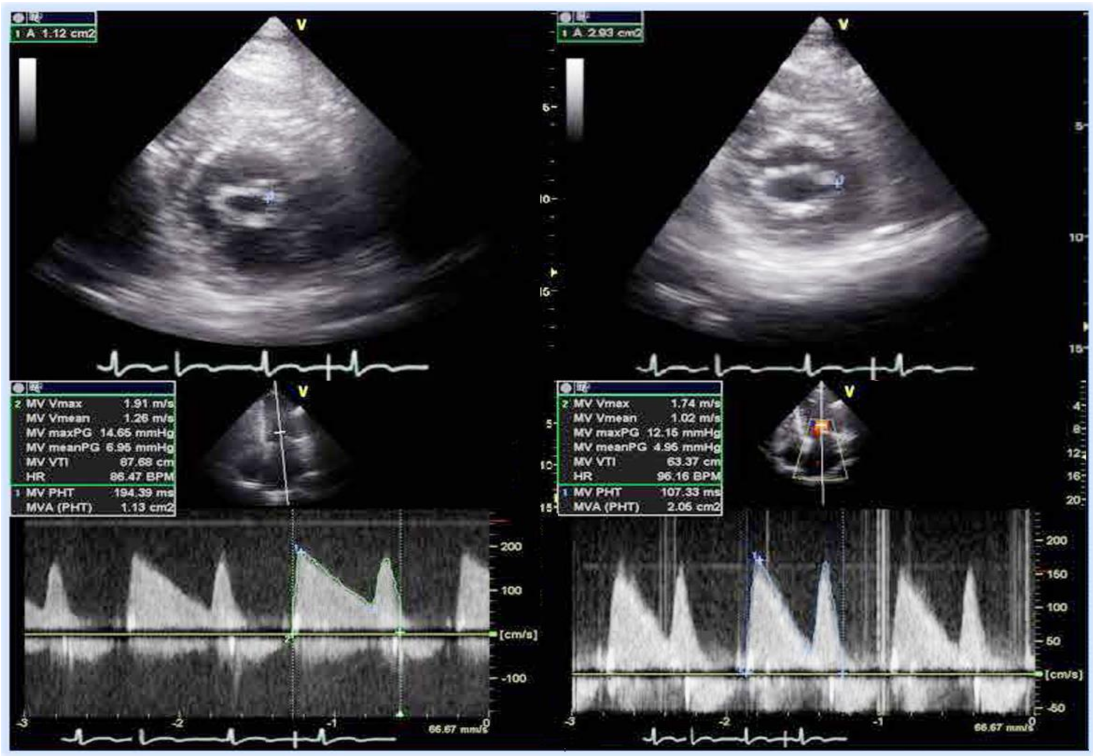


**Figure (2):**

Upper left image shows: MVA by planimetry in PSAX view pre BMV, upper right image shows: MVA by planimetry in PSAX view at follow up (after 1 year).

Lower left image shows: MPG across MV and MVA by PHT pre BMV, lower right image shows: MPG across MV and MVA by PHT at follow up (after 1 year).

Estimation of RVSP was done by placing continuous wave doppler over tricuspid valve, during ventricular systole, using the modified Bernoulli equation and adding 5 to 15 mmHg according to inferior vena cava (IVC) diameter and respiratory collapse.

### *2.2 Statistical analysis*

The data was statistically analyzed by a statistical software package (SPSS version 16). Quantitative variables were expressed as mean ± SD. Qualitative variables were compared by the use of x2 test. Quantitative variables were assessed with the unpaired-t test. A value of $P \leq 0.05$ was considered significant.

## 3. Results

This study included 70 cases, 53 of which are females (75.71%), with a mean age of 34.7 ± 12.08 years. Their body mass index (BMI) was between 15.6 and 38.7 Kg/m$^2$ with an average of 26.28 ± 5.35 Kg/m$^2$. Their body surface area (BSA) was between 1.3 and 2.3 m$^2$ with a mean of 1.72 ± 0.19 m$^2$. (Table 1)

**Table (1):** Demographic / anthropometric data of the patients

| | Range | | | Mean | ± | SD |
|---|---|---|---|---|---|---|
| **Age (Years)** | 15 | - | 62 | 34.714 | ± | 12.081 |
| **BSA (m2)** | 1.3 | - | 2.3 | 1.721 | ± | 0.198 |
| **BMI (kg/m2)** | 15.6 | - | 38.7 | 26.284 | ± | 5.351 |

| | | N | % |
|---|---|---|---|
| **Sex** | **Female** | 53 | 75.71 |
| | **Male** | 17 | 24.29 |

The majority of the patients were in sinus rhythm (80%) and only 20% had suffered from AF. Post BMV, 13 patients (92.85%) had successfully been cardioverted to sinus rhythm, while only one patient's cardioversion had failed. Wilkins score ranged from 6 to 11 with an average of 8.48 ± 1.13.

### *3.1 Echocardiographic parameters of mitral stenosis pre and post BMV*

All echocardiographic parameters of mitral stenosis (MVA, MPG, RVSP) improved in a highly significant manner ($p < 0.01$) when comparing pre BMV with immediately post BMV findings.

MVA by 2D planimetry increased from 1.00 ± 0.25 $cm^2$ to 2.33 ± 0.5 $cm^2$ and by PHT increased from 0.99 ± 0.21 $cm^2$ to 2.25 ± 0.46 $cm^2$. The MPG significantly decreased from 14.51 ± 6.55 mmHg to 5.35 ± 2.44 mmHg. The RVSP dropped from 54.35 ± 21.69 mmHg to 36 ± 13.74 mmHg.

At follow up (after 1 year), there was no significant change in MVA and RVSP compared to immediately post BMV findings. However, there was a significant increase in MPG to 5.99 ± 2.93 cm2 compared to MPG measured immediately post BMV. (Table 2)

**Table (2):** Parameters of mitral stenosis pre-BMV and post-BMV (immediately after & 1 year after)

| **Time** | **MVA by planimetry ($cm^2$)** | | | | | | | **Differences** | | **Paired Test** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Mean** | **±** | **SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 0.55 | - | 1.65 | 1.000 | ± | 0.251 | **P-PI** | -1.332 | 0.491 | -22.679 | <0.001* |
| **Post Immediately** | 1 | - | 3.6 | 2.331 | ± | 0.500 | **P-P1Y** | -1.244 | 0.657 | -15.846 | <0.001* |
| **Post 1 Year** | 1 | - | 4.1 | 2.244 | ± | 0.655 | **PI-P1Y** | 0.088 | 0.470 | 1.559 | 0.124 |

| **Time** | **MVA by PHT ($cm^2$)** | | | | | | | | | **Paired Test** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Mean** | **±** | **SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 0.55 | - | 1.5 | 0.994 | ± | 0.212 | **P-PI** | -1.258 | 0.501 | -21.010 | <0.001* |
| **Post Immediately** | 1.2 | - | 3.4 | 2.252 | ± | 0.460 | **P-P1Y** | -1.245 | 0.586 | -17.771 | <0.001* |
| **Post 1 Year** | 0.9 | - | 3.87 | 2.239 | ± | 0.584 | **PI-P1Y** | 0.013 | 0.452 | 0.241 | 0.811 |
| **Time** | **Mean PG (mmHg)** | | | | | | | | | **Paired Test** | |
| | | | | **Mean** | **±** | **SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 6 | - | 33 | 14.519 | ± | 6.552 | **P-PI** | 9.167 | 5.940 | 12.912 | <0.001* |
| **Post Immediately** | 1.6 | - | 15 | 5.352 | ± | 2.445 | **P-P1Y** | 8.521 | 5.931 | 12.020 | <0.001* |
| **Post 1 Year** | 2 | - | 21 | 5.997 | ± | 2.938 | **PI-P1Y** | -0.645 | 2.316 | -2.332 | 0.023* |
| **Time** | **RVSP (mmHg)** | | | | | | | | | **Paired Test** | |
| | | | | **Mean** | **±** | **SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 25 | - | 140 | 54.357 | ± | 21.694 | **P-PI** | 18.357 | 13.192 | 11.642 | <0.001* |
| **Post Immediately** | 18 | - | 105 | 36.000 | ± | 13.742 | **P-P1Y** | 17.436 | 18.330 | 7.958 | <0.001* |
| **Post 1 Year** | 17 | - | 77 | 36.921 | ± | 8.960 | **PI-P1Y** | -0.921 | 12.852 | -0.600 | 0.551 |

P:pre, PI:post-immediately, P1Y:post 1 year

None of the patients had more than moderate MR pre BMV, however 48.57 % of them had mild MR prior to valvuloplasty. Immediately post procedure, 24.29 % had no MR, 37.14% had mild MR, 32.86 % had moderate MR and 5.71% had moderate to severe MR. None of the patients developed severe MR post procedure. At follow up (after 1 year), 38.57% had no MR, 44.29% had mild MR, 11.43 % had moderate MR and 5.71% had moderate to severe MR.

Tricuspid regurgitation improved significantly after procedure with 2.86% of the patients having moderate to severe TR unlike prior to the procedure where 8.57% had moderate to severe TR. At follow up (after 1 year), only 1.43% had moderate to severe TR.

### *3.2 Invasive hemodynamic measurements during procedure*

There wasn't any significant change in mean right atrial pressure (RAP), right ventricle end-diastolic pressure (RVEDP) or left ventricle end-diastolic pressure (LVEDP). However, the remaining pressures showed highly significant changes ($p < 0.01$) with RVSP dropping from 54.35 ± 21.69 mmHg to 36 ± 13.74 mmHg; systolic PAP from 51.17 ± 19.94 mmHg to 34.8 ± 11.64 mmHg; mean LAP dropped from 27.1 ± 6.67 mmHg to 14.92 ± 5.06 mmHg and pressure gradient across the mitral valve measured immediately post valvotomy dropped from 15.24 ± 5.6 mmHg to 5.35 ± 2.44 mmHg.

### *3.3 Left atrial assessment by 2D echocardiography*

All left atrial diameters were significantly reduced post BMV. LA-AP diameter dropped from 48.11 ± 5.28 mm to 46.19 ± 5.87 mm, LA minor length (septo-lateral) dropped from 51.54 ± 5.54 mm to 49.16 ± 6.81 mm and LA major length (supero-inferior) dropped from 66.07 ± 5.96 mm to 63.6 ± 7.1 mm with all showing highly significant drop ($p < 0.01$).

At follow up (after 1 year), there was no significant change in LA-AP diameter and LA major length but LA minor length showed significant drop from 49.16 ± 6.81 mm to 47.46 ± 5.3 mm. Figure (3)

Regarding left atrial area measured post BMV at the end of the ventricle systole (with maximal left atrial size); left atrial end-systolic area (LAESA) showed a significant decrease from 30.72 ± 5.95 $cm^2$ to 28.03 ± 6.72 $cm^2$, as well as the indexed area which dropped from 17.9 ± 3.41 $cm^2/m^2$ to 16.27 ± 3.64 $cm^2/m^2$. A significant decrease was also seen in left atrial area measured at the end of the ventricular diastole (with minimal left atrial size); as left atrial end diastolic area (LAEDA) dropped from 25.28 ± 6.11 $cm^2$ to 21.31 ± 6.54 $cm^2$, the same was noticed in the indexed area which dropped from 14.71 ± 3.47 $cm^2/m^2$ to 12.33 ± 3.53 $cm^2/m^2$.

At follow up (after 1 year), there was no significant change in LAESA, LAESAI, LAEDA and LAEDAI.

LAESV (LAVmax) as well as LAEDV (LAVmin) showed significant decrease in the immediate phase post BMV. LAESV dropped from 116.94 ± 35.91 mL to 99.81 ± 37.63 mL, LAESVI dropped from 68.18 ± 20.2 $mL/m^2$ to 57.84 ± 20.68 $mL/m^2$, while LAEDV decreased from 86.9 ± 34.53 mL to 65.35 ± 32.79 mL and LAEDVI from 50.56 ± 19.36 $mL/m^2$ to 37.62 ± 17.9 $mL/m^2$.

At follow up, there wasn't any significant change in LAEDV or LAEDVI but there has been a significant drop in LAESV from 99.81 ± 37.63 mL to 93.05 ± 29.82 mL and in LAESVI from 57.84 ± 20.68 mL to 54.07 ± 16.43 $mL/m^2$. Figure (3)

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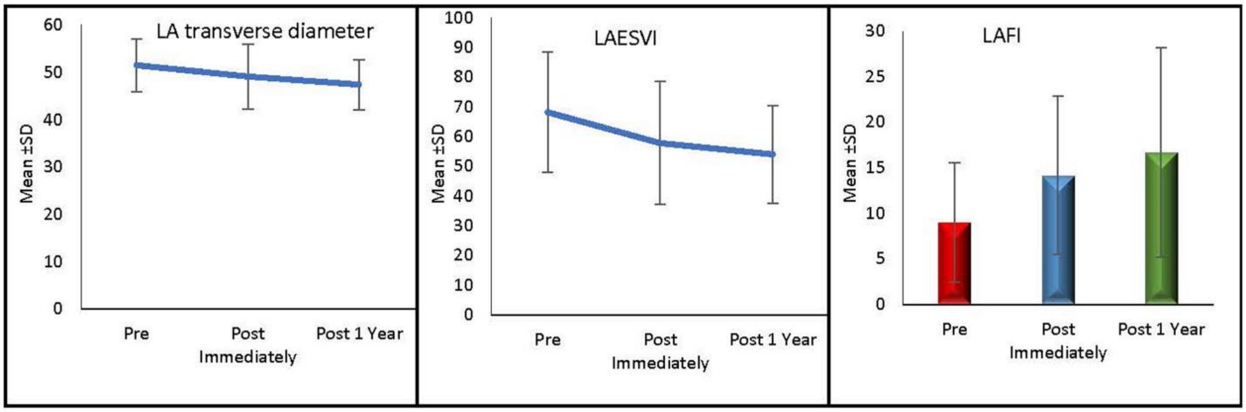


**Figure (3):** Three charts showing significant improvement of LA transverse diameter (left), LAESVI (middle) and LAFI (right) immediately post BMV and at 1 year after BMV.

In the immediate phase post BMV, Left atrial total emptying fraction (LATEF) being calculated as (LAESV-LAEDV)/ LAESV x 100 significantly increased (p<0.01) from 27.04 ± 11.39 % to 36.54 ± 11.95 %. Left atrial function index (LAFI) being calculated as (LATEF x LVOT VTI in cm)/LAESVI x 100 in mL/m$^2$ also improved significantly (p<0.01) from 9 ± 6.52 to 14.16 ± 8.68. At follow up, there wasn't any significant change in LATEF but there has been a significant increase in LAFI from 14.16 ± 8.68 to 16.71 ± 11.49, Figure (3). Thus, LAFI significant improvement at follow up is inversely proportional to LAESVI significant drop. (Table 3)

**Table (3):** Mean and SD of LA diameters, areas, volumes, total LAEF and LAFI pre and post (immediately after & 1 year after) BMV

| **Time** | **LAEDV (ml)** | | | **Differences** | | **Paired Test** | |
|---|---|---|---|---|---|---|---|
| | | **Mean±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 37-206 | 86.908±34.532 | **P-PI** | 21.557 | 20.602 | 8.754 | <0.001* |
| **Post Immediately** | 20-193 | 65.351±32.790 | **P-P1Y** | 25.647 | 27.406 | 7.830 | <0.001* |
| **Post 1 Year** | 12-132 | 61.261±27.745 | **PI-P1Y** | 4.090 | 23.927 | 1.430 | 0.157 |
| **Time** | **LAEDVI (ml/m2)** | | | | | **Paired Test** | |
| | | **Mean±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 20-115.8 | 50.563±19.363 | **P-PI** | 12.941 | 12.472 | 8.681 | <0.001* |
| **Post Immediately** | 11-113.5 | 37.621±17.900 | **P-P1Y** | 15.207 | 15.914 | 7.995 | <0.001* |
| **Post 1 Year** | 6.3-82.5 | 35.356±15.314 | **PI-P1Y** | 2.266 | 13.489 | 1.405 | 0.164 |
| **Time** | **LAEDA (cm$^2$)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 14-43 | 25.284±6.116 | **P-PI** | 3.968 | 3.890 | 8.534 | <0.001* |
| **Post Immediately** | 10-43 | 21.316±6.549 | **P-P1Y** | 4.164 | 5.610 | 6.211 | <0.001* |
| **Post 1 Year** | 7.8-46 | 21.120±7.036 | **PI-P1Y** | 0.196 | 4.786 | 0.343 | 0.733 |
| **Time** | **LAEDAI (cm2/m2)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 7.8-25.2 | 14.713±3.471 | **P-PI** | 2.379 | 2.386 | 8.345 | <0.001* |
| **Post Immediately** | 5.2-25.2 | 12.334±3.532 | **P-P1Y** | 2.496 | 3.279 | 6.369 | <0.001* |
| **Post 1 Year** | 4-27 | 12.217±3.816 | **PI-P1Y** | 0.116 | 2.711 | 0.359 | 0.721 |
| **Time** | **LAESV (ml)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 60-250 | 116.943±35.915 | **P-PI** | 17.127 | 23.964 | 5.980 | <0.001* |
| **Post Immediately** | 35-248 | 99.816±37.638 | **P-P1Y** | 23.890 | 28.472 | 7.020 | <0.001* |
| **Post 1 Year** | 36-165 | 93.053±29.821 | **PI-P1Y** | 6.763 | 27.982 | 2.022 | 0.047* |
| **Time** | **LAESVI (ml/m2)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 31.5-131.5 | 68.188±20.203 | **P-PI** | 10.344 | 14.404 | 6.008 | <0.001* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Post Immediately** | 24.2-145.8 | 57.844±20.689 | **P-P1Y** | 14.116 | 16.189 | 7.295 | <0.001* |
| **Post 1 Year** | 19-101.6 | 54.071±16.433 | **PI-P1Y** | 3.773 | 15.772 | 2.001 | 0.049* |
| **Time** | **LAESA (cm$^2$)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 17-48 | 30.722±5.958 | **P-PI** | 2.690 | 4.607 | 4.885 | <0.001* |
| **Post Immediately** | 14.3-50 | 28.032±6.720 | **P-P1Y** | 2.955 | 5.151 | 4.799 | <0.001* |
| **Post 1 Year** | 16-55 | 27.767±6.437 | **PI-P1Y** | 0.265 | 4.724 | 0.469 | 0.641 |
| **Time** | **LAESAI (cm2/m2)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 11-27 | 17.909±3.417 | **P-PI** | 1.636 | 2.752 | 4.972 | <0.001* |
| **Post Immediately** | 8.4-29.4 | 16.273±3.642 | **P-P1Y** | 1.734 | 3.040 | 4.773 | <0.001* |
| **Post 1 Year** | 9-32.3 | 16.174±3.629 | **PI-P1Y** | 0.099 | 2.681 | 0.308 | 0.759 |
| **Time** | **LATEF %** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 4-49 | 27.041±11.396 | **P-PI** | -9.498 | 9.504 | -8.362 | <0.001* |
| **Post Immediately** | 11-60 | 36.540±11.950 | **P-P1Y** | -9.967 | 12.701 | -6.566 | <0.001* |
| **Post 1 Year** | 9-66 | 37.009±13.565 | **PI-P1Y** | -0.469 | 11.172 | -0.351 | 0.727 |
| **Time** | **LAFI** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 0.5-37 | 9.001±6.525 | **P-PI** | -5.162 | 6.039 | -7.152 | <0.001* |
| **Post Immediately** | 2-43 | 14.163±8.681 | **P-P1Y** | -7.714 | 10.037 | -6.430 | <0.001* |
| **Post 1 Year** | 1.4-59 | 16.714±11.491 | **PI-P1Y** | -2.551 | 7.947 | -2.686 | 0.009* |
| **Time** | **LA** major Length A4C (mm) | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 53-79 | 66.074±5.966 | **P-PI** | 2.473 | 3.646 | 5.674 | <0.001* |
| **Post Immediately** | 42-80 | 63.601±7.104 | **P-P1Y** | 1.933 | 5.332 | 3.033 | 0.003* |
| **Post 1 Year** | 46.7-81.3 | 64.141±7.361 | **PI-P1Y** | -0.540 | 4.279 | -1.056 | 0.295 |
| **Time** | **LA** minor Length A4C (mm) | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 43-71 | 51.544±5.544 | **P-PI** | 2.379 | 4.409 | 4.514 | <0.001* |
| **Post Immediately** | 35-72 | 49.166±6.815 | **P-P1Y** | 4.083 | 5.530 | 6.177 | <0.001* |
| **Post 1 Year** | 35-61.3 | 47.461±5.308 | **PI-P1Y** | 1.704 | 4.564 | 3.125 | 0.003* |
| **Time** | **LA AP diameter in PLAX (mm)** | | | | | **Paired Test** | |
| | | **Mean ±SD** | | **Mean** | **SD** | **t** | **P-value** |
| **Before BMV** | 35-61 | 48.110±5.288 | **P-PI** | 1.916 | 2.985 | 5.370 | <0.001* |
| **Post Immediately** | 32-59 | 46.194±5.873 | **P-P1Y** | 2.069 | 4.897 | 3.534 | 0.001* |
| **Post 1 Year** | 34.2-66 | 46.041±6.603 | **PI-P1Y** | 0.153 | 4.016 | 0.318 | 0.751 |

### *3.4 Left ventricle (LV) assessment by 2D echocardiography*

LV end systolic diameter (LVESD) showed non-significant increase in the immediate phase post BMV, while LV ejection fraction (LVEF) significantly increased from 61.02 ± 7.28 % to 62.71 ± 4.78 %. At follow up, there wasn't any significant change in LVEF but LVESD showed significant increase from 32.35 ± 4.08 mm to 33.31 ± 4.16 mm. There has been a significant increase in both LVESD and LVEF at follow up in comparison to the measurements pre BMV.

## 4. Discussion

BMV is considered to have an impact on remodeling of LA structure and function. In our study, we evaluated 70 patients who underwent successful BMV more than 1 year ago and compared the results to those before and immediately after BMV to determine the long-term results on LA function.

The mean planimetry-derived MVA after BMV was significantly improved from 1.00 ± 0.25 $cm^2$ to 2.33 ± 0.5 $cm^2$ and by PHT from 0.99 ± 0.21 $cm^2$ to 2.25 ± 0.46 $cm^2cm^2$ with marked improvement in RVSP which dropped from 54.35 ± 21.69 mmHg to 36 ± 13.74 mmHg and a drop in MPG across the MV from 14.51 ± 6.55 $cm^2$ to 5.35 ± 2.44 $cm^2$. These results were consistent with [11] who studied 531 patients before and after BMV for 5 years as well as [12] who studied 52 patients. The MVA improvement in our study was even more superior to these mentioned studies, as the resulting MVA post BMV in [11] was 1.95 ± 0.29 $cm^2$ and in [12] was 1.73 ± 0.22 $cm^2$.

At follow up, 1 year after BMV, there was no significant change in these parameters except for MPG across the MV which showed a significant increase from 5.35 ± 2.44 $cm^2$ to 5.99 ± 2.93 $cm^2$. This may be related to the unstable hemodynamic condition in the immediate phase after BMV which is due to the immediate significant improvement of LA compliance post BMV [13].

In our study, none of the patients had more than moderate MR pre BMV, however 48.57 % of them had mild MR prior to valvuloplasty. Immediately post procedure, 32.86 % had moderate MR and 5.71% had moderate to severe MR. At follow up, 11.43 % had moderate MR and 5.71% had moderate to severe MR.

This reduction in moderate MR is explained by Palacios and colleagues who discussed three possible mechanisms causing the decrease in MR: “1) reversible MV stretching by BMV, 2) fibrosis and healing of the commissures end, which may decrease MR due to the excessive commissural splitting, and 3) improvement in temporary papillary muscle dysfunction induced by balloon trauma during BMV”. We also believe that in our study, improvement in excessive commissural damage could be the cause behind this reduction in MR [14].

TR improved significantly after procedure with 2.86% of the patients having moderate to severe TR unlike prior to the procedure where 8.57% had moderate to severe TR. At follow up (after 1 year), only 1.43% had moderate to severe TR. This consistent improvement in TR is due to the significant reduction in RVSP immediately post procedure which is maintained unchanged after 1 year of BMV.

Left atrial parameters showed highly significant changes immediately after BMV with a further significant improvement 1 year after procedure. This includes a significant immediate improvement in LA antero-posterior diameter, LA longitudinal diameter, LA transverse diameter, LAESA, LAESAI, LAEDA, LAEDAI, LAESV, LAESVI, LAEDV, LAEDVI, total LAEF and LAFI. The further significant improvement 1 year after the procedure was mainly in the LA transverse diameter, LAESV, LAESVI and LAFI.

This was in concordance with a study done by [15] that stated a significant decrease in LA maximal and minimal volumes 72 hours after BMV in a study of patients with severe MS. The study showed drop in LAESV from 58.8 ± 7.9 mL to 45.4 ± 6.9 mL and in LAEDV from 39 ± 6.9 mL to 28 ± 4.4 mL.

Also in concordance with a study done by [16] that showed a significant decrease of LAESVI, LAEDVI and LA-AP diameter with a significant increase in LATEF 72 hours after BMV and further significant improvement at 1 year after the procedure. However, in our study, the consistent significant improvement 1 year after BMV was mainly in the LA transverse diameter, LAESV, LAESVI and LAFI.

These previous results regarding LA volumes in our study was also in concordance with a study done by [17] that studied 30 MS patients with successful BMV and reported that at 1 year follow up after BMV, there wasn’t any significant change in LV end diastolic volume index compared to baseline with a significant decrease in LV end systolic volume index.

In our study, LVESD showed non-significant increase in the immediate phase post BMV, while LVEF significantly increased from 61.02 ± 7.28 % to 62.71 ± 4.78 %. LVEF significant increase in this case might be explained by a significant increase in LV end diastolic diameter (LVEDD) immediately after BMV due to the increase in LV diastolic filling, while LVESD showed no significant change. These findings are consistent with a study done by [18] which showed that increase of LV end-diastolic volume was the only parameter that determined increased global longitudinal strain (GLS) after BMV, and hence rapid improvement of LV deformation and function.

In another study done by [19] to determine the effects of BMV on LV function, there was a significant increase in LV ejection fraction 24 h after BMV but with a non-significant increase in LV end-diastolic volume.

The RVSP decrease after BMV followed by improved interactions between left and right ventricles could be another possible factor responsible for LV function improvement noticed in MS patients after valvotomy [20].

At follow up in our study, there wasn't any significant change in LVEF but LVESD showed significant increase from 32.35 ± 4.08 mm to 33.31 ± 4.16 mm. LVEF non-significant change at follow up might be explained by the continuous increase in LVEDD together with the significant increase in LVESD at follow up.

### *4.1 Study Limitations*

Only 14 out of 70 patients in our study had suffered from AF. So, further studies on MS patients who had experienced AF and the impact of that on their left atrial function after valvotomy are required. Also, our study aimed at the assessment of the LA function of patients 1 year after BMV, therefore further studies with longer term follow-up periods are required for better assessment of left atrial reverse remodeling following successful percutaneous mitral valvotomy.

## 5. Conclusions

BMV has good immediate and long-term results leading to a significant improvement of LA volumes and function.

Compliance with Ethical Standards
No funding was available.

Conflict of Interest
No conflict of interest.
The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

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