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Left Ventricular longitudinal Strain before and after Percutaneous Balloon Mitral Valvuloplasty

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ABSTRACT

Background: Two-dimensional speckle tracking echocardiography with longitudinal strain analysis is a valuable tool for quantifying left ventricular systolic function in patients with severe mitral stenosis post-percutaneous mitral balloon valvotomy, the established standard treatment for symptomatic severe MS with favorable valve morphology.

Objectives: This study aimed to assess left ventricular function before and after percutaneous balloon mitral commissurotomy by using 2D speckle tracking echocardiography.

Patients and methods: This was a prospective study that was carried out on 30 patients with severe mitral stenosis undergoing trans-catheter mitral valve commissurotomy using Inoue balloon. Measurement of left ventricular function was performed before and 30 days after PMBV by conventional and two-dimensional strain echocardiography (global longitudinal peak systolic strain).

Results: Comparing differences in measurements before and 30 days after balloon mitral valvuloplasty, there were significant improvement in left ventricle (LV) systolic functions according to EF and LV dimensions. As regards longitudinal strain results, there was significant improvement in global longitudinal strain, LVAP2 chamber, LVAP3 chamber and LVAP4 chamber strains. The longitudinal strain of all heart walls showed significant improvement except the inferior wall showed non-significant changes.

Conclusion: 2D strain echocardiography revealed enhanced LV systolic function parameters in patients with severe MS following successful PMBV.

Keywords: Left ventricular function, Mitral stenosis, Percutaneous mitral balloon, Two-dimensional speckle tracking echocardiography, Valvuloplasty.

INTRODUCTION

Mitral stenosis (MS) remains a widespread valvular heart disease globally, particularly prevalent in regions with high rates of rheumatic fever, especially in underdeveloped countries [(1)].

Treatment for symptomatic patients with moderate to severe MS aims to alleviate the mechanical obstruction caused by the stenosis. This can be achieved through percutaneous mitral balloon valvotomy (PMBV) or surgical intervention on the mitral valve [(2)]. PMBV is widely recognized as the standard treatment for individuals with symptomatic severe mitral stenosis and favorable valve morphology [(3)]. Patient selection for PMBV relies on a quantitative scoring system that assesses valve characteristics and commissural calcification [(4, 5)].

Numerous studies have explored the immediate and long-term outcomes following PMBV [(6)]. This study aimed to evaluate the impact of successful PMBV on left ventricular systolic function, as measured by strain echocardiography, in patients with severe MS.

PATIENTS AND METHODS

The study included 30 patients with severe mitral stenosis who were admitted to Mabarrah Misr Al-Qadema hospital (Cairo, Egypt) and Menoufia University Hospital to undergo trans-catheter mitral valve commissurotomy at the period from 1st of August 2023 to 31th of July 2024.

Exclusion criteria: Patients with severe mitral valve calcification and moderate and severe mitral regurgitation were excluded.

Transthoracic echocardiographic examination was done by Philips IE 30 (Philips Medical Systems, USA) machine and balloon mitral valvotomy (BMV) was planned according to echo findings, speckle tracking echocardiography was done and repeated 30 days after the procedure. All examinations were recorded for offline analysis. Images were imported into a Q-lab software for analysis of global longitudinal strain (GLS) of the myocardium from the average of 17 segments.

Ethical approval: Informed consent was taken from each patient after been informed about the procedures and its possible complication. Approval was obtained from The Ethical Committee of Scientific Research of Faculty of Medicine, Menoufia University under code no. (6/2021CARD32). This work had been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA) program was used and data was summarized as mean and standard deviation (SD) for normally distributed variables using the paired sample t-test. A p-value was considered statistically significant if ≤ 0.05.

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RESULTS

This study included 30 patients diagnosed with severe mitral stenosis and mitral valve area (MVA) ≤ 1.5 cm^2 (Wilkins score 8 ± 1). The patients were assessed by Two- dimension echocardiography and speckle tracking and were followed-up 1 month after percutan

eous balloon mitral valvuloplasty using single balloon technique with Inoue balloon size (26 – 28 mm). Patients included in this study aged from 27 to 45 years with a mean 39 ± 9 years. Males were 5 (16.7%) and females were 25 (83.3%). A

ccording to the recorded risk factors, 1 patient had DM (3.3%), 5 patients were hypertensive (16.7 %), 4 patients were smokers (13.3%) and 5 patients were recorded dyslipidemic (16.7%). The average blood pressure of the participants was recorded 124 ± 13 / 79 ± 8 and their heart rhythm was recorded sinus rhythm in 20 patients (66.7%) and atrial fibrillation in 10 patients (33.35%).

None of the participants had concomitant aortic stenosis, 6 patients (20%) had mild aortic regurgitation. About half of patients had mild to moderate tricuspid regurgitation. Also, 14 patients (46.7%) had mild pulmonary regurgitation and 6 patients (20%) had moderate pulmonary regurgitation, while 10 patients (33%) were free of pulmonary regurgitation. 9 (30%) patients developed grade I/IV MR post-commissurotomy, seven (23.33%) patients developed grade II/IV MR after BMVP (Table 1).

Table (1): Demographic characteristics and valvular lesions of the participants

		N (total 30)	%	
Gender	**Male**	5	16.7%	
	Female	25	83.3%	
Age (Mean ± SD)		39 ± 9		
DM		1	3.3%	
HTN		5	16.7%	
Smoking		4	13.3%	
Average systolic blood pressure		124 ± 13		
Average diastolic blood pressure		79 ± 8		
Rhythm	**Sinus**	20	66.7%	
	AF	10	33.3%	
Valvular lesions rather than mitral stenosis				
			N	**%**
Aortic valve stenosis		**No**	30	100%
Aortic valve regurgitation		**No**	23	76.7%
		Mild	6	20%
		Moderate	1	3.3%
Tricuspid valve regurgitation		**No**	4	13.3%
		Mild	17	56.7%
		Moderate	9	30%
Pulmonary valve stenosis		**No**	27	90 %
		Mild	3	10%
Pulmonary valve regurgitation		**No**	10	33.3%
		Mild	14	46.7%
		Moderate	6	20%
Mitral valve regurgitation grade before and 30 days after balloon mitral valvuloplasty				
Mitral valve regurgitation grade before BMV		**No**	20	66.7%
		grade ¼	10	33.3%
Mitral valve regurgitation grade after BMV		**No**	14	46.67%
		grade ¼	9	30 %
		grade 2/4	7	23.33%

Data are presented as frequency (%), **BMV:** balloon mitral valvuloplasty. Data are presented as mean ± Standard Deviation, **DM:** Diabetes Mellitus; **HTN:** Hypertension; **RHD:** Rheumatic Heart Disease; **AF**: Atrial Fibrillation; **SD:** Standard Deviation.

Echocardiographic findings showed that LV end-diastolic dimensions (LVEDD), end-diastolic volume (EDV), mitral valve area and EF by M mode (pre-61±7% - post 64±7%) were significantly increased 30 days after BMVP, while LV end-systolic dimensions (LVESD), end systolic volume (EDV), left atrial diameter, mean pressure gradient (MPG), maximum pressure gradient across mitral valve and the estimated RV end-systolic pressure (ERVSP) were significantly decreased 30 days after BMVP (Table 2 and figures 1 & 2).

Table (2): Conventional echocardiographic findings, mitral valve gradients and area of patients before and 30 days after percutaneous balloon valvuloplasty.

	Pre-operative	**Post-operative**	**P-value**
	Mean ± SD	**Mean ± SD**	
LVEDD (mm)	45.00 ± 0.92	47.57 ± 0.83	**<0.001***
LVESD (mm)	32.5 ± 13.5	30.77 ± 0.82	**0.001***
EDV (MM-Teich) (ml)	105.57 ± 4.7	109.13 ± 4.85	**0.029***
ESV (MM-Teich) (ml)	44.23 ± 2.69	40.23 ± 2.58	**0.002***
LVPWs (mm)	13.8 ± 2.27	13.9 ± 1.3	0.09
LVPWd (mm)	9.1 ± 1.65	9.87 ± 1.36	0.35
IVSs (mm)	12.1 ± 1.67	13 ± 1.76	0.21
IVSd (mm)	8.83 ± 1.51	9.83 ± 1.51	0.76
Aortic Diameter (mm)	23.8 ± 4.8	24.53 ± 4.66	0.061
LA Diameter (mm)	47.6 ± 4.96	41.27 ± 3.61	**<0.001***
EF M-mode	0.61 ± 0.07	0.64 ± 0.07	**<0.001***
RVESP (mmHg)	52.8 ± 9.17	43.63 ± 6.99	**<0.001***
MAX Gradient across MV (mmHg)	26.43 ± 7.44	16.9 ± 4.84	**<0.001***
MEAN Gradient across MV (mmHg)	14.6 ± 4.35	7 ± 1.72	**<0.001***
MVA planimetry (cm^2)	1.11±0.15	1.84±0.15	**<0.001***

Data are presented as mean ± Standard Deviation**,** *: Significant p value ≤0.05**. EDV**: end-diastolic volume. **ESV**: end-systolic volume. **EF:** Ejection fraction. **IVSd**: Inter-ventricular septum in diastole. **IVSs**: Inter-ventricular septum in systole. **LA**: Left atrium. **LVPWd**: Left ventricle posterior wall in diastole. **LVPWs**: Left ventricle posterior wall in systole. **LVESD**: Left ventricle end-systolic diameter. **LVEDD**: Left ventricle end- diastolic diameter. **MV**: mitral valve. **RVESP**: right ventricular end-systolic artery pressure.

As regards longitudinal strain results, there was significant improvement in the global longitudinal strain (p=0.03), LVAP2 chamber (p=0.002), LVAP3 chamber (p=0.009) and LVAP4 chamber (p=0.01) strains 30 days after PMBV. The longitudinal strain of LV lateral, septal, anterior, anteroseptal and inferolateral walls showed significant improvement while the inferior wall showed non-significant improvement (p=0.59) (Table 3 and figures 3 & 4)).

Table (3): Longitudinal LV strain values pre and post balloon mitral valvuloplasty

	Pre-operative		**Post-operative**		**P-value**
	Mean	**SD**	**Mean**	**SD**	
LV global longitudinal Strain (%)	18	3	20	3	**0.03**
LV AP2 chamber strain (%)	18	5	20	4	**0.002**
Anterior wall strain (%)	16	10	23	10	**<0.001**
Inferior wall strain (%)	19	8	18	7	0.59
LV AP3 chamber strain (%)	17	8	22	6	**0.009**
ANT-SEP wall strain (%)	14	5	19	2.3	**0.02**
INF-LAT wall strain (%)	13	12	20	15	**0.02**
LV AP4 chamber strain (%)	18	4	23	8	**0.01**
Lateral wall strain (%)	15	10	21	9	**0.04**
Septal wall strain (%)	14	4	18	2	**0.03**

Data are presented as mean ± Standard Deviation**,** *: Significant p value ≤0.05, **LVAP:** left ventricular apical projection.

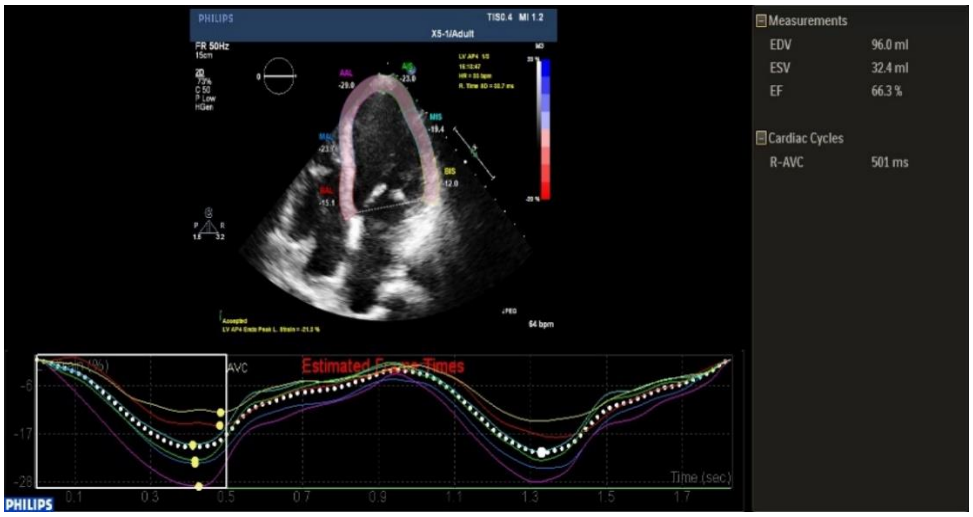

Figure (1): Pre PMVB case 1.

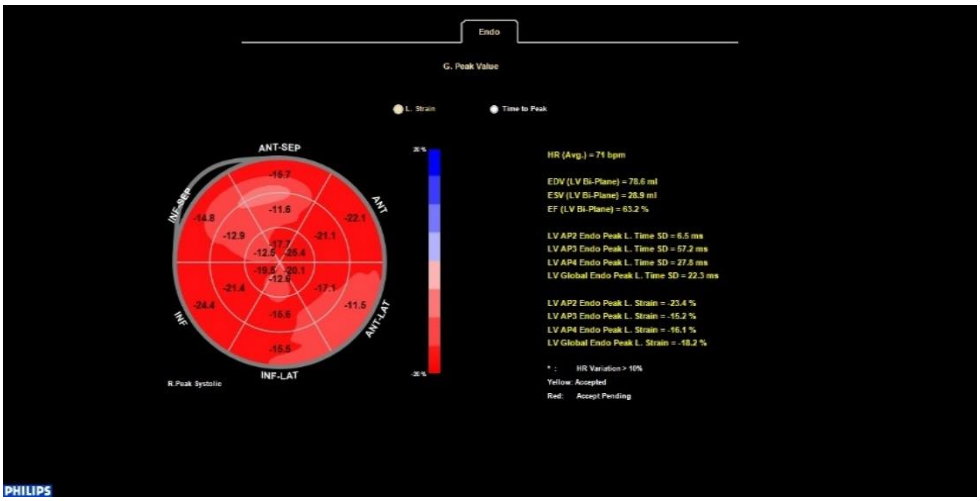

Figure (2): Post P.MBV case 1.

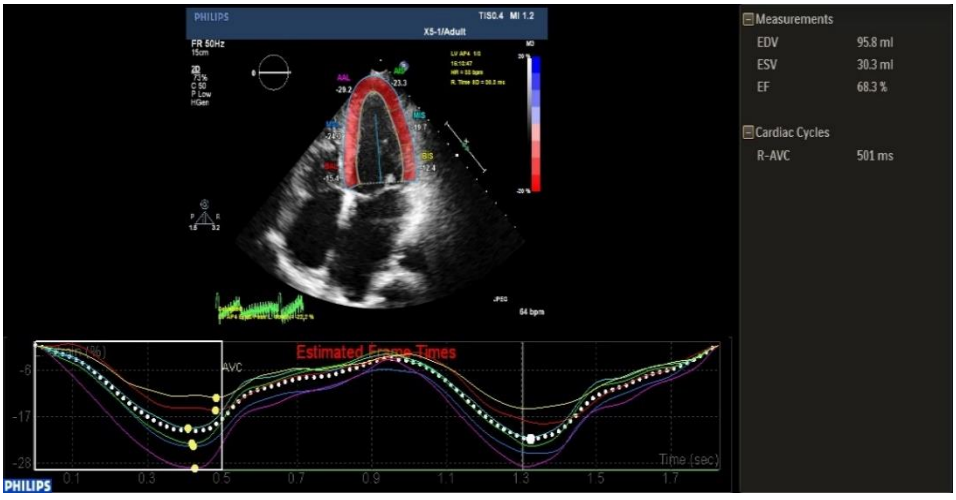

Figure (3): Pre PMBV case 2.

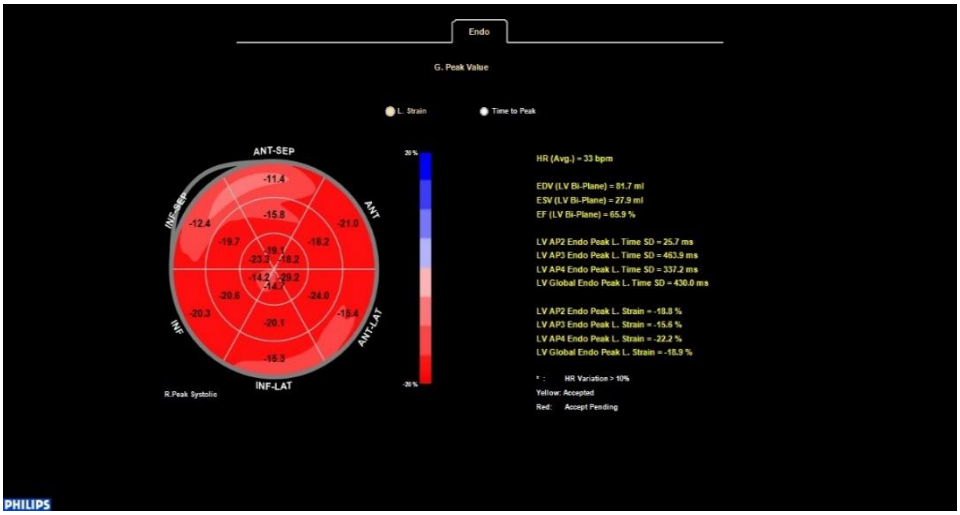

Figure (4): Post PMBV case 2.

DISCUSSION

Mitral stenosis (MS) is a chronic rheumatic heart valve disease that often leads to pulmonary hypertension but rarely results in left ventricular (LV) systolic dysfunction [7].

Conventional echocardiography parameters measured before and 30 days after balloon mitral valvuloplasty (BMV) demonstrated significant increases in LVEDD, EDV, MVA, and EF, while significant decreases were observed in LVESD, ESV, left atrial diameter, MPG, and EPASP.

Our findings align with **Esteves *et al.*** [8], who reported significant increases in LVEF, LV end-diastolic volume, and stroke volume following BMV. Similarly, **Pamir *et al***. [9] did not observe acute changes in EF after BMV, which is consistent with our findings.

Longitudinal strain echocardiography revealed improved LV function post-BMV, likely due to increased preload, reduced afterload, decreased pulmonary artery pressure, and improved interventricular septum movement.

Increases in LVAP2, LVAP3, and LVAP4 chamber strains were observed in all walls except the inferior wall, which is consistent with the findings of **Bektas *et al.*** [10], **Sengupta *et al.*** [11], and **Barros-Gomes *et al.*** [12]. Furthermore, our results align with **Samaan *et al.*** [13], who noted improvements in LV deformation and ejection fraction after BMV, suggesting reversible myocardial dysfunction.

The absence of improvement in the inferior wall is consistent with **Galli *et al.*** [14], who reported motion abnormalities in the postero-basal wall in MS patients, potentially due to a tethering effect from the rigid mitral valve apparatus.

As proposed by **Klein *et al.*** [15], acute rheumatic fever can lead to delayed mitral stenosis, and the inflammatory process can cause fibrosis in heart layers. **Waller *et al.*** [16] found Aschoff bodies in excised stenotic mitral valves, suggesting myocardial fibrosis. This fibrosis can extend to the myocardium, affecting strain echocardiography results in MS patients compared to the general population, as explained by **Ozdemir *et al.*** [17], **Leitman and Vered** [18], and **Roushdy *et al.*** [19]. Alternatively, image quality issues may contribute to tracking inaccuracies [20].

CONCLUSIONS

A significant improvement in LV systolic function was observed post-PMBV in patients with severe MS, as assessed by 2D strain echocardiography.

LIMITATIONS

In this study, we faced a limited number of cases, the dependence of echocardiographic speckle tracking on high-quality images, and that the patients included in our study represented only one category of mitral stenosis patients.

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