Evaluation of the effect of percutaneous mitral balloon valvuloplasty on left ventricular systolic functions using strain and strain rate echocardiography

Abstract

Background/ Aim: This study aimed to evaluate the effect of successful percutaneous mitral balloon valvuloplasty (PMBV) on left ventricular systolic functions using strain and strain rate echocardiography in moderate-severe mitral stenosis (MS) patients with normal left ventricular systolic function confirmed by conventional echocardiography.

Materials and Methods: Patients with moderate-severe MS, who had undergone successful PMBV, were included. Conventional echocardiographic parameters were evaluated before and after PMBV. Peak systolic strain and strain rate values of basal, mid, and apical segments of the left ventricular anterior, inferior, septum, and lateral walls were determined.

Results: After PMBV, significant decreases were determined in the peak and mean gradients of the mitral valve and pulmonary artery pressure, but a significant increase in the mitral valve area. Significant increases (improvement) were determined in the peak systolic strain and strain rate in the basal, mid and apical segments of the left ventricular septum, lateral, anterior, and inferior walls and in the left ventricular global peak systolic strain (-17.32±0.58% vs. -12.38±1.06%) and strain rate (-1.65±0.07 vs. -1.22±0.12).

Conclusion: Strain and strain rate echocardiography can be used for quantitative evaluation of the effect of PMBV on the left ventricular systolic functions in moderate-severe MS patients.

Key words: Mitral stenosis, mitral valvuloplasty, echocardiography, doppler, strain-strain rate

1. Introduction

Mitral stenosis (MS) is a valvular heart disease, which remains as an important cause of morbidity and mortality worldwide, particularly in developing countries. It generally appears as a late-term complication of acute rheumatic fever [1]. Mitral stenosis leads to hemodynamic disorders by inhibiting left ventricular filling. Disease progression results in left ventricular dysfunction, pulmonary hypertension, and right heart failure [2]. In general, depending on the patient's status, percutaneous intervention or surgery is recommended for the treatment of moderate-severe MS patients (mitral valve area <1.5 cm^2) and/or symptomatic patients [3]. Percutaneous mitral balloon valvuloplasty (PMBV) is an effective therapeutic option for the treatment of MS and is successfully performed in selected MS patients based on the hemodynamic and echocardiographic criteria [4, 5].

Echocardiography is the method of choice for the diagnosis of MS and the assessment of disease severity [6]. The opportunity for more detailed and comprehensive examination has arisen with technological developments and the availability of three-dimensional echocardiography [7]. Strain and strain rate echocardiography, a method based on the principal of tissue Doppler, has been defined for the quantification of regional myocardial function [8]. Strain and strain rate echocardiography came into use in the late 1990s as a method of measuring ventricular performance [9]. Strain defines the change in the size of an object, in other words deformation, as a result of a force applied to that object and is expressed as percentage (%) and strain rate is the rate of deformation [9]. It is thought that strain and strain rate echocardiography may enhance the accuracy, quality, and reproducibility of test interpretations and diagnostic performance by allowing quantitative evaluation of the ventricular wall movements [10]. The role of strain and strain rate echocardiography in clinical practice would be better understood with an increasing number of comparative studies. The aim of this study was to investigate the effect of successful PMBV on left ventricular systolic functions by strain and strain rate echocardiographic parameters using tissue Doppler in moderate-severe MS patients with normal left ventricular systolic functions confirmed by conventional echocardiography techniques.

2. Materials and Methods

This prospectively designed study included patients with moderate-severe MS, who had undergone a successful PMBV procedure in our clinic within a 10-month period. Patients with diabetes mellitus, arterial hypertension, coronary artery disease, chronic renal failure, atrial fibrillation, left ventricular ejection fraction (EF) <50%, segmental wall movement abnormalities, left bundle branch block, moderate-severe aortic stenosis, aortic insufficiency, moderate-severe tricuspid stenosis and who developed mechanical complications such as severe mitral regurgitation, pericardial tamponade and cardiac perforation during PMBV were excluded. The study was approved by the local Ethics Committee of Erciyes University School of Medicine and informed consent was obtained from all the patients.

Echocardiography was performed both before and one month after the PMBV. Transthoracic echocardiographic images of the patients were recorded at end-expiration by the same surgeon using the 2.5 MHz electronic transducer of a Vivid 7 Echocardiography device (GE Vingmed Ultrasound, Horten, Norway) while the patients were lying in the left lateral recumbent position. The left atrium diameter and the left ventricular systolic and diastolic diameters were measured on the parasternal long axis images, and EF and fractional shortening (FS) were measured using the Teichholz method. Planimetric valve area was measured on the parasternal short axis images. EF was calculated with the Simpson’s rule on the apical 4- and 2-chamber images, the peak and mean mitral valve gradient was calculated with continuous wave (CW) Doppler, and mitral valve area was calculated with the pressure half-time (PHT) method. In addition, pulmonary artery systolic pressure was measured using the CW Doppler tracing of the tricuspid regurgitation jet. The right ventricle size was also measured. The presence and the degree of mitral insufficiency, aortic insufficiency, and tricuspid regurgitation were determined using a color tissue Doppler. Color tissue Doppler images were obtained from the apical 4- and 2-chamber views at a frame rate of >90 frame/s and recorded at the end-expiration over three respiratory cycles. The peak systolic strain and peak systolic strain rates of the basal, mid, and apical segments of the left ventricular anterior, inferior, septum, and lateral walls were obtained on the apical 4- and 2-chamber tissue Doppler images and the left ventricular global peak systolic strain and strain rates were calculated with their mean values.

2.1. Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences version 15 for Windows software (SPSS Inc., Chicago, IL, USA). Conformity of the variables to normal distribution was assessed with the Shapiro–Wilks test. Because the data was distributed normally, statistical data were stated as mean ± standard deviation (X ± SD) and paired sample *t* test was used to compare the variables before and after PMBV. A p value <0.05 was considered statistically significant.

3. Results

Evaluation was made of 30 patients, comprising 23 females and 7 males with a mean age of 46±11 years. Conventional echocardiography findings of the patients before and after PMBV are presented in Table 1. There were significant decreases in the mitral valve peak gradient, mean gradient, and pulmonary artery pressure after PMBV compared with those values before PMBV. A significant increase was determined in the mitral valve area after PMBV, which was measured using planimetry and the PHT method. There was no significant change in the

EF and FS after PMBV. Peak systolic strain values and strain rates before and after PMBV are presented in Table 2 and Table 3, respectively.

A significant increase (improvement) was determined in the global peak systolic strain and strain rates of the septum, anterior, inferior, and lateral walls after PMBV. Changes in the left ventricular global peak systolic strain and strain rates are shown in Figure 1 and Figure 2, respectively.

4. Discussion

In the presence of mitral stenosis, left ventricular functions are influenced through numerous mechanisms and at various degrees. Although conventional echocardiography demonstrates that left ventricular functions are usually preserved in patients with pure MS, subclinical dysfunctions can be detected with the availability of new methods. Ozer et al. [11] conducted a tissue Doppler study in pure MS patients and a healthy control group and found the left ventricular global functions, evaluated by FS, to be similar in the two groups, although systolic velocity, which was measured from the left ventricular septal and lateral mitral annulus, was found to be significantly lower in the MS group than in the control group. Similarly, Ozdemir et al. [12] conducted a tissue Doppler study and found the left ventricular wall annular velocity to be significantly lower in the pure MS patients compared to the healthy control subjects. In another tissue Doppler study by Sengupta et al. [13], it was determined that systolic and diastolic mitral annular velocities were lower in the MS patients than in the healthy control group. It was also shown that these velocities increased after percutaneous mitral commissurotomy.

Strain and strain rate have been reported to be beneficial and sensitive parameters in assessing myocardial functions [14]. The fact that strain and strain rate measurements are not influenced by the tethering effect of adjacent myocardial segments is the most important advantage over tissue Doppler echocardiography. Strain and strain rate echocardiography has been clinically used in the management of cardiac resynchronization therapy, evaluation of systolic and diastolic functions, determination of myocardial ischemia and vitality, and identification of early-stage (subclinical) myocardial dysfunction and infarct segments [15-23]. The normal values of systolic longitudinal strain and peak systolic strain rate have been reported to be -19±6% and -1.27±0.39 s^{-1}, respectively and the normal values of systolic radial strain and strain rate have been reported to be 41±4.4% and 2.3±0.3 s^{-1}, respectively. Inter observer variability for the strain and strain rate measurements has been found to be lower than 15% [24].

Subclinical left ventricular systolic dysfunction, which cannot be detected on M-Mod, 2-dimension echocardiography, or Doppler echocardiography, can be detected early using the strain and strain rate echocardiography. Dogan et al. [25] conducted a tissue Doppler study on mild-moderate MS patients and a healthy control group and found the peak systolic strain rate (1.2±0.4 vs. 1.8±0.39 s^{-1}, $p<0.001$) and end-systolic strain (10±5 vs. 25±6%) values to be significantly lower in the MS patients compared to the control group ($p<0.001$), although the MS patients had normal global systolic functions. In a study by Simsek et al. [26] conducted on pure MS patients with normal systolic functions and healthy control subjects, the values of systolic strain and strain rate in all segments of all myocardial walls were found to be significantly lower in the MS group. Bilen et al. [27] demonstrated deterioration in the left ventricular functions regardless of the hemodynamic severity of the stenosis in patients with MS compared to healthy individuals, using 2D strain and strain rate analyses.

The literature has a limited number of studies investigating the effect of PMBV on the left ventricular systolic functions using the strain and strain rate values. Dray et al. [28] demonstrated that strain and strain rate values obtained from the lateral wall mitral annulus systolic velocity were significantly increased after PMBV in a 14-year-old girl with severe mitral stenosis but normal left ventricular systolic functions were confirmed by conventional measurements. Based on that case, it was emphasized that strain and strain rate should be measured after the surgery to demonstrate that left ventricular changes could be reversible in MS patients. Bektas et al. [29] measured the left ventricular long-axis strain and strain rate one day before and seven days after surgery in 30 patients with moderate-severe MS undergoing PMBV. Significant decreases were determined in the lateral, inferior, anterior, and septal systolic strain values after the surgery, although there was reported to be no significant change in the strain rate values. Sengupta et al. [30] compared pre-procedure and post-procedure strain echocardiography findings of 57 patients with severe MS undergoing PMBV and determined a significant improvement in the global longitudinal strain and global circumferential strain values after PMBV. Barros-Gomes et al. [31] reported that global longitudinal strain values were strong predictors of long-term prognosis in MS patients with EF ≥50%, who underwent a successful PMBV.

The present study investigated the effect of PMBV on the systolic strain and strain rate values in the basal, mid, and apical segments of the left ventricular lateral, septum, anterior, and inferior walls in adult patients with MS. Considering the conventional parameters, significant improvements were determined in the mitral valve area, mitral valve pressure gradient, and pulmonary artery pressure after PMBV. While there were no significant changes in the EF and FS values, which are the indicators of left ventricular systolic functions, significant increases (improvement) were determined after PMBV in the systolic strain and strain rates in all segments of the myocardial walls in all patients. Thus, with the use of the strain and strain rate echocardiography technique, the present study quantitatively demonstrated that the left ventricular systolic functions were improved after PMBV. The increase in the left ventricular systolic strain and strain rate values might be related to the increase in preload and cardiac output, the decrease in afterload, the decrease in the left ventricular wall stress, and the improvement in the interventricular septum movement with decreasing pulmonary artery pressure.

Patients with mitral stenosis can remain asymptomatic for many years through self-limitation of effort capacity. However, the absence of symptoms does not change the fact that the disease is progressing. The symptoms may be subjective and misleading. In the light of the present study, PMBV can be planned for patients who are asymptomatic except for having classical indications for PMBV but with subclinical left ventricular dysfunction detected using the strain and strain rate technique.

Limitations of the present study could be said to be the low number of patients and the short follow-up period. In addition, the fact that tissue Doppler imaging is angle-dependent can be considered another limitation.

In conclusion, left ventricular systolic dysfunction can be detected using the strain and strain rate technique in MS patients with normal left ventricular functions confirmed by conventional echocardiography techniques. Strain and strain rate echocardiography can be used as a quantitative method to assess the effect of PMBV on the left ventricular systolic functions in patients with moderate-severe MS.

References

1. Harb SC, Griffin BP. Mitral valve disease: A comprehensive review. Current Cardiology Reports 2017; 19(8): 73. doi: 10.1007/s11886-017-0883-5
2. Carabello BA. Modern management of mitral stenosis. Circulation 2005; 112(3): 432-437. doi: 10.1161/CIRCULATIONAHA.104.532498
3. Martin AK, Mohananey D, Ranka S, Riha H, Núñez-Gil IJ, Ramakrishna H. The 2017 European Society of Cardiology (ESC)/European Association of Cardiothoracic Surgeons (EACTS) Guidelines for Management of Valvular Heart Disease-Highlights and Perioperative Implications. Journal of Cardiothoracic and Vascular Anesthesia 2018; pii:S1053–0770 (18): 30347-1. [Epub ahead of print]. doi: 10.1053/j.jvca.2018.05.015
4. Telila T, Mohamed E, Jacobson KM. Endovascular therapy for rheumatic mitral and aortic valve disease: Review article. Current Treatment Options in Cardiovascular Medicine 2018; 20(7): 59. doi: 10.1007/s11936-018-0647-6
5. Passeri JJ, Dal-Bianco JP. Percutaneous balloon mitral valvuloplasty: Echocardiographic eligibility and procedural guidance. Interventional Cardiology Clinics 2018; 7(3): 405-413. doi: 10.1016/j.iccl.2018.04.003
6. Mrsic Z, Hopkins SP, Antevil JL, Mullenix PS. Valvular Heart Disease. Primary Care 2018; 45(1): 81-94. doi: 10.1016/j.pop.2017.10.002
7. de Agustin JA, Nanda NC, Gill EA, de Isla LP, Zamorano JL. The use of three-dimensional echocardiography for the evaluation of and treatment of mitral stenosis. Cardiology Clinics 2007; 25(2): 311-318. doi: 10.1016/j.ccl.2007.06.008
8. D'hooge J, Heimdal A, Jamal F, Kukulski T, Bijnens B, et al. Regional strain and strain rate measurements by cardiac ultrasound: Principles, implementation and limitations. European Journal of Echocardiography 2000; 1(4): 154-170. doi: 10.1053/euje.2000.0031

9. Gilman G, Khandheria BK, Hagen ME, Abraham TP, Seward JB, Belohlavek M. Strain rate and strain: A step-by-step approach to image and data acquisition. Journal of the American Society of Echocardiography 2004; 17(9): 1011-1120. doi: 10.1016/j.echo.2004.04.039

10. Pislaru C, Abraham TP, Belohlavek M. Strain and strain rate echocardiography. Current Opinion in Cardiology 2002; 17(5): 443-454. doi: 10.1097/00001573-200209000-00002

11. Ozer N, Can I, Atalar E, Sade E, Aksöyek S, et al. Left ventricular long-axis function is reduced in patients with rheumatic mitral stenosis. Echocardiography 2004; 21(2): 107-112. doi: 10.1111/j.0742-2822.2004.03064.x

12. Ozdemir K, Altunkeser BB, Gök H, Içli A, Temizhan A. Analysis of the myocardial velocities in patients with mitral stenosis. Journal of the American Society of Echocardiography 2002; 15(12): 1472-1478. doi: 10.1067/mje.2002.128645

13. Sengupta PP, Mohan JC, Mehta V, Kaul UA, Trehan VK, et al. Effects of percutaneous mitral commissurotomy on longitudinal left ventricular dynamics in mitral stenosis: Quantitative assessment by tissue velocity imaging. Journal of the American Society of Echocardiography 2004; 17(8): 824-828. doi: 10.1016/j.echo.2004.04.025

14. Hashimoto I, Li X, Hejmadi Bhat A, Jones M, Zetts AD, Sahn DJ. Myocardial strain rate is a superior method for evaluation of left ventricular subendocardial function compared with tissue doppler imaging. Journal of the American College of Cardiology 2003; 42(9): 1574-1583. doi: 10.1016/j.jacc.2003.05.002

15. Yu CM, Fung JW, Zhang Q, Chan CK, Chan YS, et al. Tissue doppler imaging is superior to strain rate imaging and postsystolic shortening on the prediction of reverse remodeling in both ischemic and nonischemic heart failure after cardiac resynchronization therapy. Circulation 2004; 110(1): 66-73. doi: 10.1161/01.CIR.0000133276.45198.A5

16. Støylen A, Skjelvan G, Skjaerpe T. Flow propagation velocity is not a simple index of diastolic function in early filling. A comparative study of early diastolic strain rate and strain rate propagation, flow and flow propagation in normal and reduced diastolic function. Cardiovascular Ultrasound 2003; 1: 3. doi: 10.1186/1476-7120-1-3
17. Kowalski M, Herregods MC, Herbots L, Weidemann F, Simmons L, et al. The feasibility of ultrasonic regional strain and strain rate imaging in quantifying dobutamine stress echocardiography. European Journal of Echocardiography 2003; 4(2): 81-91. doi: 10.1053/euje.2002.0174
18. Hoffmann R, Altiok E, Nowak B, Heussen N, Kühl H, et al. Strain rate measurement by doppler echocardiography allows improved assessment of myocardial viability inpatients with depressed left ventricular function. Journal of the American College of Cardiology 2002; 39(3) 443-449. doi: 10.1016/s0735-1097(01)01763-6
19. Garot J, Derumeaux GA, Monin JL, Duval-Moulin AM, Simon M, et al. Quantitative systolic and diastolic transmyocardial velocity gradients assessed by m-mode colour doppler tissue imaging as reliable indicators of regional left ventricular function after acute myocardial infarction. European Heart Journal 1999; 20(8): 593-603. doi: 10.1053/euhj.1998.1335
20. Jamal F, Kukulski T, Sutherland GR, Weidemann F, D'hooge J, et al. Can changes in systolic longitudinal deformation quantify regional myocardial function after an acute infarction? An ultrasonic strain rate and strain study. Journal of the American Society of Echocardiography 2002; 15(7): 723-730. doi: 10.1067/mje.2002.118913
21. Firstenberg MS, Greenberg NL, Smedira NG, Castro P, Thomas JD, Garcia MJ. The effects of acute coronary occlusion on noninvasive echocardiographically derived systolic

and diastolic myocardial strain rates. Current Surgery 2000; 57(5): 466-472. doi: 10.1016/s0149-7944(00)00296-8

22. Iwahashi N, Nakatani S, Kanzaki H, Hasegawa T, Abe H, Kitakaze M. Acute Improvement in Myocardial Function Assessed by Myocardial Strain and Strain Rate After Aortic Valve Replacement for Aortic Stenosis. Journal of the American Society of Echocardiography 2006; 19(10): 1238-1244. doi: 10.1016/j.echo.2006.04.041

23. Bauer F, Eltchaninoff H, Tron C, Lesault PF, Agatiello C, et al. Acute improvement in global and regional left ventricular systolic function after percutaneous heart valve implantation in patients with symptomatic aortic stenosis. Circulation 2004; 110(11): 1473-1476. doi: 10.1161/01.CIR.0000134961.36773.D6

24. Voigt JU, Flachskampf FA. Strain and strain rate. New and clinically relevant echo parameters of regional myocardial function. Zeitschrift für Kardiologie 2004; 93(4): 249-258. doi: 10.1007/s00392-004-0047-7

25. Dogan S, Aydin M, Gursurer M, Dursun A, Onuk T, Madak H. Prediction of subclinical left ventricular dysfunction with strain rate imaging in patients with mild to moderate rheumatic mitral stenosis. Journal of the American Society of Echocardiography J Am Soc Echocardiogr 2006; 19(3): 243-248. doi: 10.1016/j.echo.2005.09.014

26. Simşek Z, Karakelleoğlu S, Gündoğdu F, Aksakal E, Sevimli S, et al. Evaluation of left ventricular function with strain/strain rate imaging in patients with rheumatic mitral stenosis. Anadolu Kardiyoloji Dergisi 2010; 10(4): 328-333. doi: 10.5152/akd.2010.091

27. Bilen E, Kurt M, Tanboga IH, Kaya A, Isik T, et al. Severity of mitral stenosis and left ventricular mechanics: A speckle tracking study. Cardiology 2011; 119(2): 108-115. doi: 10.1159/000330404

28. Dray N, Balaguru D, Pauliks LB. Abnormal left ventricular longitudinal wall motion in rheumatic mitral stenosis before and after balloon valvuloplasty: A strain rate imaging study. Pediatric Cardiology 2008; 29(3): 663-666. doi: 10.1007/s00246-007-9047-5
29. Bektaş O, Günaydin ZY, Karagöz A, Vural A, Kaya A, et al. Evaluation of the effect of percutaneous mitral balloon valvuloplasty on left ventricular systolic function via strain and strain rate in patients with isolated rheumatic mitral stenosis. The Journal of Heart Valve Disease 2015; 24(2): 204-209.
30. Sengupta SP, Amaki M, Bansal M, Fulwani M, Washimkar S, et al. Effects of percutaneous balloon mitral valvuloplasty on left ventricular deformation in patients with isolated severe mitral stenosis: A speckle-tracking strain echocardiographic study. Journal of the American Society of Echocardiography 2014; 27(6): 639-647. doi: 10.1016/j.echo.2014.01.024
31. Barros-Gomes S, Eleid MF, Dahl JS, Pislaru C, Nishimura RA, et al. Predicting outcomes after percutaneous mitral balloon valvotomy: the ımpact of left ventricular strain ımaging. European Heart Journal - Cardiovascular Imaging 2017; 18(7): 763-771. doi: 10.1093/ehjci/jew160

Figure 1. Changes in the left ventricular global peak systolic strain after percutaneous mitral balloon valvuloplasty

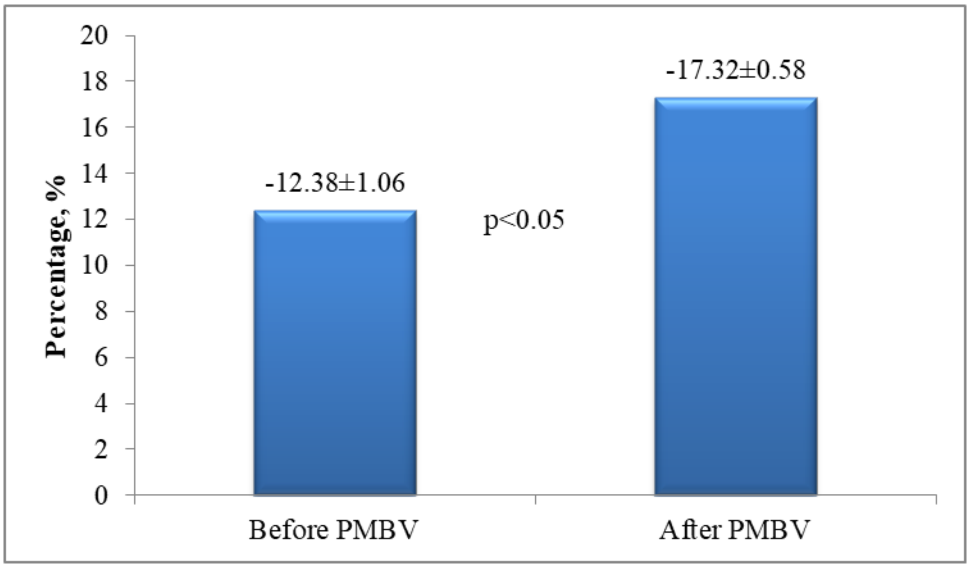

Figure 2. Changes in the left ventricular global peak systolic strain rate after percutaneous mitral balloon valvuloplasty

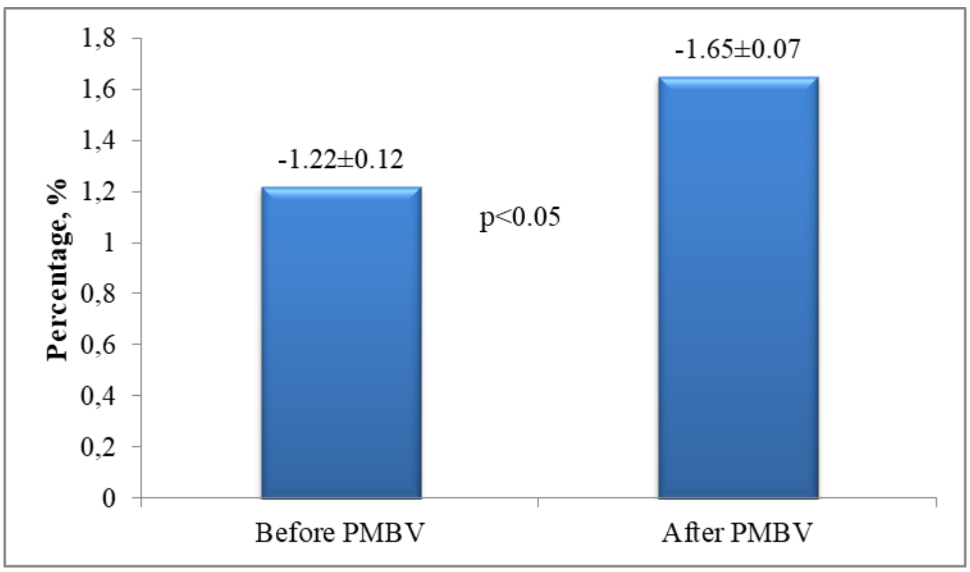

Table 1. Conventional echocardiography findings of the patients before and after percutaneous balloon valvuloplasty

	Before PMBV Mean±SD	After PMBV Mean±SD	p
LVDD, cm	4.66±0.62	4.68±0.46	0.88
LVSD, cm	3.19±0.54	2.98±0.42	**<0.05**
EF % (Teichholz method)	62.57±7.60	65.46±5.84	0.12
EF % (Simpson's rule)	61.80±5.29	62.03±3.65	0.66
FS %	33.75±6.09	37.59±4.56	0.06
LA, cm	4.62±0.74	4.34±0.87	0.06
RV, cm	3.58±0.40	3.51±0.41	0.21
PAP, mmHg	48.83±15.11	36.62±8.93	**<0.05**
Peak Gradient, mmHg	20.36±7.29	10.33±2.01	**<0.05**
Mean Gradient, mmHg	11.61±3.36	5.12±1.28	**<0.05**
MVA, planimetry, cm^2	1.16±0.19	1.93±0.28	**<0.05**
MVA, PHT, cm^2	1.09±0.21	1.82±0.25	**<0.05**

PMBV: Percutaneous mitral balloon valvuloplasty; LVDD: Left ventricular diastolic diameter; LVSD: Left ventricular systolic diameter; EF: Ejection fraction; FS: Fractional shortening; LA: Left atrium; RV: Right ventricle; PAP: Pulmonary artery pressure; MVA: Mitral valve area; PHT: Pressure half-time; SD, Standard deviation.

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Table 2. Strain values before and after the percutaneous mitral balloon valvuloplasty

	Peak Systolic Strain, %		
	Before PMBV Mean±SD	**After PMBV** Mean±SD	**p**
Myocardial wall segment			
Lateral			
Basal	-12.58±1.59	-16.47±3.10	**<0.05**
Mid	-12.51±1.82	-16.91±1.05	**<0.05**
Apical	-11.10±1.50	-17.22±0.97	**<0.05**
Septum			
Basal	-13.41±1.96	-16.11±0.96	**<0.05**
Mid	-12.21±1.77	-16.79±2.98	**<0.05**
Apical	-12.44±1.72	-17.21±1.01	**<0.05**
Anterior			
Basal	-13.68±1.75	-18.11±1.09	**<0.05**
Mid	-12.59±1.52	-18.56±1.07	**<0.05**
Apical	-12.54±1.73	-17.34±1.03	**<0.05**
Inferior			
Basal	-11.86±1.33	-18.07±0.91	**<0.05**
Mid	-10.90±1.48	-17.44±0.87	**<0.05**
Apical	-12.44±1.99	-16.64±1.01	**<0.05**
Left ventricular global	-12.38±1.06	-17.32±0.58	**<0.05**

PMBV: Percutaneous mitral balloon valvuloplasty; SD, Standard deviation.

Table 3. Strain rates before and after the percutaneous mitral balloon valvuloplasty

	Peak Systolic Strain Rate, s^{-1}		
	Before PMBV	**After PMBV**	**p**
	Mean±SD	Mean±SD	
Myocardial wall segment			
Lateral			
Basal	-1.05±0.21	-1.48±0.11	**<0.05**
Mid	-1.13±0.13	-1.55±0.12	**<0.05**
Apical	-1.18±0.15	-1.64±0.13	**<0.05**
Septum			
Basal	-1.24±0.22	-1.55±0.13	**<0.05**
Mid	-1.11±0.14	-1.51±0.19	**<0.05**
Apical	-1.21±0.14	-1.62±0.12	**<0.05**
Anterior			
Basal	-1.22±0.17	-1.76±0.16	**<0.05**
Mid	-1.24±0.15	-1.67±0.11	**<0.05**
Apical	-1.31±0.11	-1.75±0.12	**<0.05**
Inferior			
Basal	-1.18±0.17	-1.53±0.12	**<0.05**
Mid	-1.24±0.21	-1.66±0.08	**<0.05**
Apical	-1.25±0.14	-1.76±0.12	**<0.05**
Left ventricular global	-1.22±0.12	-1.65±0.07	**<0.05**

PMBV: Percutaneous mitral balloon valvuloplasty; SD, Standard deviation.