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Original article

Effect of percutaneous mitral balloon valvuloplasty on left atrial appendage function: Transesophageal echo study

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ABSTRACT

Background: To compare left atrial appendage (LAA) function by Doppler and Doppler tissue imaging (DTI) before and after percutaneous balloon mitral valvuloplasty (PBMV).**Materials and methods:** Fifty-nine patients with symptomatic rheumatic mitral stenosis who underwent PBMV were included in this study. LAA function was measured before and after PBMV. To study LAA function, LAA late emptying (LAALE) velocity, LAA late filling (LAALEF) velocity, and LAA area change percentage (LAAAC %) were measured. In the DTI study, tissue Doppler velocities of the LAA, including peak early diastolic (E_{LAA}), peak late diastolic (A_{LAA}), and peak systolic (S_{LAA}), were measured.**Results:** There was significant increase in LAALE velocity, LAALEF velocity, E_{LAA} , A_{LAA} , S_{LAA} waves measured by Doppler and DTI after PBMV compared with baseline ($p < 0.001$) but there was no significant change in LAAAC% ($p =$ not significant). Spontaneous echo contrast was present in 10 of the 59 patients before the procedure. It completely disappeared (6 patients) or decreased (4 patients) after PBMV.**Conclusions:** Our results suggest that PBMV improves LAA function and, thereby, may have a favorable influence on future thromboembolic complications.

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1. Introduction

Rheumatic mitral stenosis (MS) is still a frequent cause of valve disease in developing countries like India. In the past, the left atrial appendage (LAA) has been considered to be a relatively useless part of cardiac anatomy, but is now recognized as a structure with important pathological implications.¹ LAA normally prevents stasis of blood due to its high compliance and contractility.^{2,3}

Chronic pressure and volume overload imposed by MS causes left atrial (LA) and LAA dysfunction leading to reduced blood flow velocities,⁴ thereby producing stasis of blood,

reduced LA and LAA ejection fraction and atrial fibrillation (AF). These factors predispose to formation of LA and LAA thrombi in MS⁵ and result in thromboembolic episodes.

Risk of cerebrovascular accident (CVA) is increased approximately five-fold in non-rheumatic AF⁶ and 17-fold in patients with MS with AF.⁶ Even patients of MS in sinus rhythm with depressed LA and LAA function are at increased risk of CVA.⁷ Assessment of LAA function is helpful in predicting the risk of thromboembolism.

Since its introduction in 1984 by Inoue et al⁸ percutaneous balloon mitral valvotomy (PBMV) has become established as a safe and effective treatment for rheumatic mitral stenosis

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with results equivalent to surgical valvotomy.⁹ Mitral valve area (MVA) is increased during balloon dilatation by commissural splitting.¹⁰ Transoesophageal echocardiography (TEE) allows semi-invasive, highly accurate imaging of the functional efficiency of LAA by LAA Doppler and Doppler tissue imaging (DTI) flow profile.⁷ MS causes decreased LAA Doppler and DTI velocities in patients even with sinus rhythm.^{4,11}

Very few studies in the literature have evaluated the impact of PBMV on LAA function so far. So, this study was undertaken to evaluate the effect of PBMV on LAA function by TEE Doppler and DTI.

2. Materials and methods

Eighty-eight patients with symptomatic severe MS ($MVA \leq 1.0 \text{ cm}^2$) who underwent PBMV in Cardiology Department of Sri Venkateswara Institute of Medical sciences, Tirupati between August 2010 and January 2012 were enrolled in our study. Those who were fulfilling the PBMV intervention criteria¹² and those who had a successful intervention only were included. Successful PBMV was defined as patients who had $MVA \geq 1.5 \text{ cm}^2$ without MR > grade 2/4.¹³ Patients with LAA/LA thrombus, MR greater than 2/4, calcific mitral valve or commissures, high Wilkins echo score¹⁴ >8 were not suitable for PBMV and hence were excluded. Patients who did not accept TEE evaluation after PBMV, critically ill patients and patients in New York Heart Association (NYHA) functional class IV, patients with AF, patients with pregnancy and patients who had hypertension, diabetes mellitus, congenital heart disease, left ventricular (LV) systolic dysfunction, history of myocardial infarction were excluded. Patients who require emergency PBMV were excluded. Patients with MR $\geq 3+$ after PBMV were also excluded. Among 88 patients, 18 patients with AF, 8 patients who failed to give consent for TEE evaluation after PBMV and 3 patients who had $\geq 3+$ MR after PBMV were excluded. Exclusion reasons are shown in Fig. 1. All patients underwent PBMV by transseptal approach using Accura balloon under fluoroscopic guidance. This study was initiated with the approval of Institutional Ethics Committee.

2.1. Echocardiographic study

2.1.1. Transthoracic echocardiography

All participants underwent transthoracic echocardiography (TTE) and TEE evaluation using available equipment (Philips

IE33 Vision 2007 system, Bothell, WA, U.S.A) before the procedure and again on the third day after PBMV. LA, LV dimensions, LV ejection fraction, LA diastolic peak pressure gradient (PPG), mean pressure gradient (MPG), pulmonary artery systolic pressure (PASP) were measured in the left lateral decubitus position with routine views (parasternal long and short axis, apical 4 chamber view) by TTE according to the American Society of Echocardiography guidelines.¹⁵ MVA was estimated by direct planimetric method on short-axis view during diastole and by pressure half-time method.¹⁶ Severe MS was defined as $MVA \leq 1.0 \text{ cm}^2$ with supportive findings of MPG > 10 mm Hg and PASP > 50 mm Hg.¹⁷

2.1.2. Transesophageal echocardiography

After completion of TTE all patients were told not to take water and food orally for at least 4 h. Patient was made to lie down in appropriate position before the procedure after keeping a peripheral venous line. Patient's oropharynx was anesthetized by topical lidocaine spray. Using a 5 MHz multiplane transesophageal probe, TEE was performed. Single lead electrocardiogram (ECG) and arterial saturation by pulse oximetry was monitored throughout the TEE procedure. The TEE probe was swallowed and routine TEE measurements were made completely. LAA was clearly imaged from the midesophagus in basal short-axis view at aortic valve level (30° – 60°) by TEE. Spontaneous echo contrast (SEC) grading, presence of thrombi, LAA area, Doppler and DTI velocity profile were imaged in this view. A mean of 3 consecutive cycles was used to calculate all echocardiography parameters.

2.1.3. LAA dimensions

LAA maximal and minimal areas were traced by drawing a line from the top of the limbus of the left upper pulmonary vein along the entire endocardial border of LAA at end systole and end diastole by correlating with ECG. LAA area change percentage (LAAAC%) was calculated according to the formula:

$$[(\text{Maximal LAA area} - \text{minimal LAA area}) / \text{maximal LAA area}] \times 100$$

2.1.4. LAA Doppler flow profile

After suitable gain and filter adjustments, LAA Doppler flow velocities were obtained by using Pulsed wave (PW) Doppler from a site approximately 1 cm below the LAA outlet cavity from the middle third of LAA with no wall artifacts. LAA late emptying (LAALE) velocity which is positive flow observed after P wave and LAA late filling (LAALEF) velocity which is negative flow immediately after LAALE velocity were recorded. A representative illustration of LAA Doppler velocities of a patient pre and post PBMV is shown in Fig. 2.

2.2. Doppler tissue examination of LAA

By placing the spectral mode of PW Doppler sample volume on LAA lateral wall midway between the LAA tip and outlet; DTI velocities were obtained after suitable gain adjustments. While recording, Doppler beam was kept as parallel as possible to myocardial wall. In the DTI records, first positive wave after the electrocardiographic P wave was displayed as

Fig. 1 – Pre-screening strategy of study cohort.

LAA : Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; LAALEV: Left Atrial Appendage Late Emptying Velocity; LAALFV: Left Atrial Appendage Late Filling Velocity.

Fig. 2 – Effect of PBMV on LAA Doppler velocities.

A_{LAA} , followed by a negative wave (S_{LAA}) coinciding with left ventricular contraction and then a positive wave (E_{LAA}) during left ventricular relaxation. Normal LAA DTI velocity profile is shown in Fig. 3. A representative illustration of LAA DTI velocities of a patient pre and post PBMV is shown in Fig. 4.

2.2.1. Statistical analysis

Data was tabulated using Excel software (Microsoft Corp. Redmond, U.S.A). Statistical analysis was done with SPSS version 13.0. Results were presented as tables and charts. Continuous variables were presented as mean $\pm$ SD and categorical variables as percentages. Nonparametric continuous variables were tested with paired sample t-test. A p -value less than 0.05 was considered to indicate statistical significance.

LAA-Left Atrial Appendage.

Fig. 3 – Tissue Doppler evaluation indices of LAA function.²⁸

3. Results

Baseline Characteristics of the population are shown in Table 1. Of 59 patients, 42 (71%) patients were female and 17 (29%) patients were male. Mean age of the patients was 33.6 ± 10.3 years. MS in all the patients had rheumatic etiology and all patients were in sinus rhythm. History of rheumatic fever was present in 17 (25%) patients. Thirty-three patients were in NYHA functional class III and 26 patients were in NYHA functional class II before PBMV. After PBMV breathlessness improved and 52 patients were in NYHA functional class I and 7 patients were in NYHA functional class II.

3.1. TTE findings

Comparison of TTE variables before and after PBMV are shown in Table 2. LA M-mode dimension did not change significantly before and after PBMV [46.4 ± 4.7 mm versus 44.9 ± 4.3 mm, p = not significant (NS)]. Mean mitral valve Wilkins echocardiographic score was 6.0 ± 0.8 . Mitral valve PPG (31.1 ± 8.3 mm Hg versus 9.3 ± 1.9 mm Hg, $p < 0.001$), MPG (20.4 ± 6.4 mm Hg versus 5.2 ± 1.2 mm Hg, $p < 0.001$) and PASP (58.7 ± 18.0 mm Hg versus 40.7 ± 12.2 mm Hg, $p < 0.001$) decreased significantly after PBMV. MVA increased significantly after PBMV (Planimetry – 0.8 ± 0.1 cm² versus 1.7 ± 0.1 cm², PHT – 0.9 ± 0.1 cm² versus 1.7 ± 0.1 cm², $p < 0.001$).

3.2. TEE findings

Spontaneous echo contrast (SEC) was present in LA and LAA in 10 of the 59 patients before procedure. SEC completely disappeared in 6 patients and decreased in 4 patients after procedure. Comparison of LAA function before and after PBMV by TEE is shown in Table 3. The same data is shown in Fig. 5 as

LAA Doppler tissue velocities
before PBMV LAA Doppler tissue velocities
after PBMV

LAA : Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; DTI: Doppler Tissue Imaging.

Fig. 4 – Effect of PBMV on LAA DTI.

bar diagram. There was no significant difference in LAAAC% after PBMV when compared with baseline value (49.3 ± 3.4 versus 50.4 ± 3.3 ; $p = \text{NS}$). LAALF (23.2 ± 7.7 cm/s versus 43.7 ± 11.7 cm/s, $p < 0.001$) and LAALF (32.9 ± 10.8 cm/s versus 41.6 ± 11.7 cm/s, $p < 0.001$) velocities measured by Doppler were increased significantly after PBMV compared with baseline. E_{LAA} (7.4 ± 2.0 cm/s versus 11.1 ± 2.4 cm/s; $p < 0.001$), A_{LAA} (12.8 ± 3.2 cm/s versus 24.6 ± 5.0 cm/s; $p < 0.001$), S_{LAA} (9.5 ± 2.1 cm/s versus 15.5 ± 2.6 cm/s; $p < 0.001$) values measured by DTI also increased significantly after PBMV compared with baseline. LAA Doppler and DTI velocities in patients with SEC and without SEC are shown in Tables 4, 5 and 6. Baseline LAA Doppler velocities (LAALF, LAALF

velocities) in patients with SEC (LAALF velocity – 17.5 ± 4.7 cm/s, LAALF velocity – 25.2 ± 6.6 cm/s) were significantly less ($p < 0.01$) than in patients without SEC (LAALF velocity – 24.6 ± 7.5 cm/s, LAALF velocity – 34.8 ± 10.8 cm/s). Baseline LAA DTI velocities were also less but statistically not significant [$(E_{\text{LAA}} - 6.5 \pm 1.9$ cm/s versus 7.6 ± 1.9 cm/s, $p = 0.12$), $(A_{\text{LAA}} - 11.3 \pm 2.8$ cm/s versus 13.0 ± 3.9 cm/s, $p = 0.11$), $(S_{\text{LAA}} - 9.0 \pm 1.4$ cm/s versus 9.4 ± 2.2 cm/s, $p = 0.60$)] in patients with SEC when compared with patients without SEC.

4. Discussion

In patients with MS, chronic stretch in LA/LAA due to pressure and volume overload causes atrial electrophysiologic and electroanatomic abnormalities.¹⁸ PBMV reverses these changes in LA and LAA by acute decrease in LA afterload as

Table 1 – Baseline characteristics of the population.

Characteristics	Patients
Age (years)	33.6 ± 10.3
Sex	
Male	17 (29%)
Female	42 (71%)
Height (cm)	155.3 ± 9.8
Duration of symptoms (months)	21.4 ± 18.4
Functional class (NYHA)	
Class I	0
Class II	26 (44%)
Class III	33 (56%)
Class IV	0
Previous Rheumatic fever	
Present	15 (25%)
Absent	44 (75%)
Previous/Past CVA	0
LA size (mm)	46.4 ± 4.7
Left ventricular ejection fraction	$60.6 \pm 5.6\%$
Wilkins score	6.0 ± 0.8

NYHA: New York Heart Association; CVA: Cerebrovascular Accident; LA: Left Atrial. Data is expressed as mean and standard deviation for continuous variables and as percentages for categorical variables.

Table 2 – Comparison of transthoracic echocardiographic variables before and after percutaneous balloon mitral valvuloplasty.

Variables	Before	After	p-value
LA (mm)	46.4 ± 4.7	44.9 ± 4.3	NS
LVEF (%)	60.6 ± 5.6	60.7 ± 5.2	NS
LV diastolic diameter (mm)	41.1 ± 5.1	41.4 ± 5.1	NS
LV systolic diameter (mm)	27.2 ± 4.2	27.3 ± 4.5	NS
Max Gr (mm Hg)	31.1 ± 8.3	9.3 ± 1.9	<0.001
Mean Gr (mm Hg)	20.4 ± 6.4	5.2 ± 1.2	<0.001
MVA PHT (cm ²)	0.8 ± 0.1	1.7 ± 0.1	<0.001
MVA plan (cm ²)	0.9 ± 0.1	1.7 ± 0.1	<0.001
PASP (mm Hg)	58.7 ± 18.0	40.7 ± 12.2	<0.001

LVEF: Left ventricular ejection fraction; LA: Left atrial diameter; LV: left ventricular; Max Gr: maximum mitral gradient; Mean Gr: mean mitral gradient; MVA: mitral valve area; PHT: pressure half-time; MVA plan: planimetric mitral valve area; PASP: pulmonary artery systolic pressure; NS: statistically not significant. Data is expressed as mean and standard deviation.

Table 3 – Comparison of LAA function before and after PBMV by TEE.

Parameter	Before PBMV	After PBMV	p-value
LAALFV (cm/s)	23.2 ± 7.7	43.7 ± 11.7	<0.001
LAALFV (cm/s)	32.9 ± 10.8	41.6 ± 11.7	<0.001
E _{LAA} (cm/s)	7.4 ± 2.0	11.1 ± 2.4	<0.001
A _{LAA} (cm/s)	12.8 ± 3.2	24.6 ± 5.0	<0.001
S _{LAA} (cm/s)	9.5 ± 2.1	15.5 ± 2.6	<0.001
LAAAC (%)	49.3 ± 3.4	50.4 ± 3.3	NS

LAA: Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; TEE: Transesophageal Echo; LAALFV: Left Atrial Appendage Late Emptying Velocity; LAALFV: Left Atrial Appendage Late Filling Velocity; LAAAC: Left Atrial Appendage Area Change Percentage; NS: statistically not significant. Data is expressed as mean and standard deviation.

evidenced by increased LAA blood flow velocities. In the present study we found significant improvement in patients clinical status and SEC grading after PBMV along with significant reduction in LA PPG, MPG, PASP and a significant increase in MVA after PBMV. We also observed a significant increase in LAA Doppler and DTI velocities after PBMV but without significant change in LAAAC%.

In patients with MS, due to low flow velocity and low shear conditions, RBC aggregates form by noncovalent binding between red cells and plasma proteins. RBC aggregates thus formed lead to increased blood echogenicity causing ultrasonic backscatter and produce a pattern of smoke or SEC in LA. SEC is associated with clot formation and embolic phenomena. SEC was graded as 0 – no smoke, 1+ – mild smoke visible in some portion of the LA and 2+ – dense smoke that appeared throughout the LA.¹⁹ SEC will form even in patients with sinus rhythm, with significantly dilated and depressed atrial function. In our study 10 (16%) patients had SEC. In patients with mitral stenosis with normal sinus rhythm, Bernstein NE et al²⁰ found SEC in the echocardiograms of 21 (45%) of 47 patients. In another study Kasliwal RR et al²¹ found that SEC in the LA was seen in 57.3% of patients on multiplane TEE. Among ten patients in our study, 6 patients had grade 1+ SEC and 4 patients had grade 2+ SEC before the procedure.

LAA: Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; TEE: Transesophageal Echo; LAALFV: Left Atrial Appendage Late Emptying velocity; LAALFV: Left Atrial Appendage Late Filling velocity; LAAAC: Left Atrial Appendage Area Change Percentage; NS: Not significant.

Fig. 5 – Comparison of LAA function before and after PBMV by TEE.**Table 4 – Comparison of LAA function before and after PBMV by TEE in patients with SEC.**

Parameter	Before PBMV	After PBMV	p-value
LAALFV (cm/s)	17.5 ± 4.7	31.6 ± 5.7	<0.001
LAALFV (cm/s)	25.2 ± 6.6	33.4 ± 8.2	<0.001
E _{LAA} (cm/s)	6.5 ± 1.9	9.7 ± 1.8	<0.001
A _{LAA} (cm/s)	11.3 ± 2.8	16.9 ± 3.7	<0.001
S _{LAA} (cm/s)	9.0 ± 1.4	14.1 ± 1.9	<0.001

LAA: Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; TEE: Transesophageal Echo; SEC: Spontaneous Echo Contrast; LAALFV: Left Atrial Appendage Late Emptying velocity; LAALFV: Left Atrial Appendage Late Filling velocity. Data is expressed as mean and standard deviation.

Table 5 – Comparison of LAA function before and after PBMV by TEE in patients without SEC.

Parameter	Before PBMV	After PBMV	p-value
LAALFV (cm/s)	24.6 ± 7.5	45.6 ± 11.5	<0.001
LAALFV (cm/s)	34.8 ± 10.8	43.8 ± 11.7	<0.001
E _{LAA} (cm/s)	7.6 ± 1.9	11.1 ± 2.3	<0.001
A _{LAA} (cm/s)	13.0 ± 3.1	24.9 ± 4.7	<0.001
S _{LAA} (cm/s)	9.4 ± 2.2	16.4 ± 2.7	<0.001

LAA: Left Atrial Appendage; PBMV: Percutaneous Balloon Mitral Valvotomy; TEE: Transesophageal Echo; SEC: Spontaneous Echo Contrast; LAALFV: Left Atrial Appendage Late Emptying velocity; LAALFV: Left Atrial Appendage Late Filling velocity. Data is expressed as mean and standard deviation.

Baseline Doppler ($p < 0.01$) and DTI velocities ($p = NS$) were less in patients with SEC when compared with patients without SEC implying more LAA dysfunction in patients with SEC. After the procedure SEC disappeared in 6 patients who had grade 1+ SEC. Remaining 4 patients who had grade 2+ SEC decreased to grade 1+ SEC. Karakaya et al²² studied 20 patients with MS in sinus rhythm. SEC was present in 7 of the 20 patients before procedure but completely disappeared (4 patients) or decreased (3 patients) after procedure. Vijay-vergiya et al²³ also noticed significant improvement in SEC grading after PBMV.

Table 6 – Comparison of LAA function in patients with and without SEC before PBMV.

Parameter	Patients with SEC	Patients without SEC	p-value
LAALFV (cm/s)	17.5 ± 4.7	24.6 ± 7.5	<0.01
LAALFV (cm/s)	25.2 ± 6.6	34.8 ± 10.8	<0.01
E _{LAA} (cm/s)	6.5 ± 1.9	7.6 ± 1.9	0.12
A _{LAA} (cm/s)	11.3 ± 2.8	13.0 ± 3.1	0.11
S _{LAA} (cm/s)	9.0 ± 1.4	9.4 ± 2.2	0.60

LAA: Left Atrial Appendage; SEC: Spontaneous Echo Contrast; PBMV: Percutaneous Balloon Mitral Valvotomy; LAALFV: Left Atrial Appendage Late Emptying velocity; LAALFV: Left Atrial Appendage Late Filling velocity. Data is expressed as mean and standard deviation.

Table 7 – Comparison of LAA Doppler velocities with other studies.

Study	MVA (cm ²) pre-PBMV	MVA (cm ²) post-PBMV	p-value	LAALEV before (cm/sec)	LAALEV after (cm/sec)	p-value	LAALFV before (cm/sec)	LAALFV after (cm/sec)	p-value
Tatani et al ²⁷	0.8	2.8	<0.05	30.0	47.0	<0.05	35.0	53.0	<0.05
Karakaya et al ²²	1 ± 0.2	2.2 ± 0.2	<0.01	31 ± 16	42 ± 15	<0.01	44 ± 18	46 ± 15	NS
Present study	0.8 ± 0.1	1.7 ± 0.1	<0.001	23.1 ± 7.7	43.7 ± 11.7	<0.001	32.9 ± 10.8	41.6 ± 11.7	<0.001

LAA: Left Atrial Appendage; MVA: Mitral valve area; LAALEV: Left Atrial Appendage Emptying Velocity; LAALFV: Left Atrial Appendage Late Filling Velocity; p-val: p-value; NS: Statistically not significant. Data is expressed as mean and standard deviation.

Table 8 – Comparison of LAA DTI velocity profile with other studies.

Study	E _{LAA} (cm/s) before	E _{LAA} (cm/s) after	p-value	A _{LAA} (cm/s) before	A _{LAA} (cm/s) after	p-value	S _{LAA} (cm/s) before	S _{LAA} (cm/s) after	p-value
Karakaya et al ²²	8 ± 4.6	22 ± 10	<0.01	29 ± 3.4	45 ± 8.2	<0.01	8.4 ± 3.4	14 ± 6.4	<0.01
Vijayvergiya et al ²³	4.6 ± 0.9	5.2 ± 0.8	<0.01	6.6 ± 1.1	7.3 ± 1.1	<0.01	4.6 ± 1.1	5.5 ± 1.1	<0.01
Present study	7.4 ± 2.0	11.1 ± 2.4	<0.001	12.8 ± 3.2	24.6 ± 5.0	<0.001	9.5 ± 2.1	15.5 ± 2.6	<0.001

LAA: Left Atrial Appendage; DTI: Doppler Tissue Imaging. Data is expressed as mean and standard deviation.

4.1. Effect of PBMV on LAAAC%

We observed no significant change in LAAAC% in our study similar to Karakaya et al²² and Vijayvergiya et al²³ studies.

4.1.1. Comparison of LAA Doppler velocities of present study with other studies

LAA pulsed Doppler emptying and filling velocities of >60 cm/sec in normal healthy controls were found in Tenekecioglu et al²⁴ study. Sahin et al²⁵ compared LAA velocities in healthy controls with sinus rhythm with MS in AF patients (peak ejection velocity – 61 ± 16 cm/sec versus 24 ± 6 cm/sec, Peak filling velocity – 50 ± 9 cm/sec versus 24 ± 7 cm/sec). LAA Doppler velocities were significantly depressed in MS patients. In our study also baseline LAA Doppler velocities were significantly decreased. Comparison of our study findings with other studies are shown in Table 7. After PBMV we found significant increase in LAALE velocity similar to Porte et al²⁶, Tatani et al²⁷, Vijayvergiya et al²³ and Karakaya et al²² studies. LAALF velocity was not significantly changed in Karakaya et al²² study, but LAALF velocity was significantly increased in other studies^{23,27} similar to our study.

4.1.2. Comparison of LAA DTI velocities with other studies

Contraction of LAA causes displacement toward the base of heart and is displayed as positive wave (A_{LAA}) on TEE DTI velocity profile. LAA does not move during LV isovolumic contraction. So after a brief delay, LAA moves toward the LV apex and is displayed as negative peak velocity (S_{LAA}), coincides with the LV contraction (T-wave on the ECG). During isovolumic relaxation LAA remains immobile and then moves again toward the base of heart. This velocity E_{LAA} corresponds to LV relaxation. Tenekecioglu et al²⁴ demonstrated A_{LAA} tissue velocity of 33 ± 4.1 cm/sec in normotensive healthy controls. Sahin et al²⁵ demonstrated LAA DTI velocities in healthy controls in sinus rhythm and in patients with MS in AF (E_{LAA} velocity – 14.9 ± 5.9 cm/sec versus 4.2 ± 1.3 cm/sec

and S_{LAA} velocity – 11.4 ± 5.1 cm/sec versus 5.6 ± 1.3 cm/sec). Comparison of our study LAA DTI findings with other studies are shown in Table 8.

In our study also LAA baseline DTI velocities were significantly low when compared with healthy controls. After PBMV both systolic and diastolic LAA DTI velocities were significantly increased ($p < 0.001$) in our study similar to Vijayvergiya et al²³ and Karakaya et al²² studies but in contrast to Bauer et al²⁸ study which showed significant increase in diastolic velocities only. Our values of pre-PBMV and post-PBMV DTI velocities of the LAA are comparable with those of Karakaya et al.²² In our study LAA tissue Doppler velocities came higher than in Vijayvergiya et al²³ and Bauer et al²⁸ as we excluded MS patients with AF, similar to Karakaya et al²² study.

In this study we found that successful PBMV improves clinical status, decreases the intensity of LA and LAA SEC and increases the LAA Doppler and DTI velocities leading to improved global and regional LA and LAA function. So, relief of MS by PBMV may not only confer hemodynamic benefits for symptomatic improvement but also may have a favorable influence on future thromboembolism risk by improving LA and LAA function.²⁹

4.2. Limitations

Absence of clinical follow up is main limitation of this study. We excluded patients with atrial fibrillation, those with high Wilkins echocardiographic scores, and those with mitral regurgitation grade ≥2, so there is a possibility of selection bias. LA and LAA volumes are not measured.

Conflicts of interest

All authors have none to declare.

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