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Left Atria Function in Mitral Stenosis: Tissue Doppler Strain Imaging Before and After Balloon Mitral Valvotomy

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Abstract

Background: The electromechanical remodelling of the atrium can be better comprehended if one has a good understanding of left atrial function. It is now possible to assess cardiac function non-invasively using techniques like tissue Doppler imaging and strain (rate) imaging. Both approaches have been proven reliable for gauging LV performance at the local level. These methods were employed in recent assessments of Left Atrial function. The Tissue Doppler Velocities, Strain, and Strain Rate of a Heart after Balloon Mitral Valve Replacement. **Material and Methods:** In 50 symptomatic patients with severe mitral stenosis, velocity, strain, and strain rate were assessed using tissue doppler imaging, echocardiography, and doppler testing. Both before and after the balloon mitral valve surgery, all patients underwent evaluation. Controls of the same age were also tested. **Results:** Decreased E' and A' IAS tissue doppler velocities were seen in patients with mitral stenosis. Patients with mitral stenosis had slower velocities in the left atrial lateral wall compared to healthy controls. After mitral balloon valvuloplasty, lateral E' velocity increased (P 0.001). Mitral stenosis patients observed lower left atrial strain at ventricular end systole compared to controls. Systolic strain in the IAS decreases and strain in the left atrial lateral wall appears to ameliorate after balloon mitral valve surgery. **Conclusion:** Mitral stenosis patients had impaired Left Atrial function, as measured by Tissue Doppler velocities and Strain. Function of the left atrial reservoir enhances after balloon mitral valve surgery.

Keywords: Strain imaging, mitral stenosis, tissue doppler mitral valvotomy, left atrial function.

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Introduction

The Left Atrium acts as a reservoir, a conduit, and a pump in a normal situation. The heart's reservoir function occurs during left ventricular systole, when the Mitral valve closes, the Left Atrium relaxes, and the Mitral annulus briefly advances toward the top of the heart. Diastole is the time when the mitral valves open and blood flows from the left atrium to the left ventricle. The left atrium contracts at the close of diastole, initiating pumping.[1]

When there is Mitral Stenosis, the left atrium may not work as well because the left atrial afterload is higher. Rheumatic mitral stenosis is marked by significant commissure fusion and a smaller area of the mitral valve. The leaflets are also less mobile. Also, the left atrium has gotten bigger, which has hurt its ability to pump blood. When atrial fibrillation is confirmed, atrial systole stops, and the Left Atrial pump no longer works.[2]

Different methods, both invasive and non-invasive, have been used in the past to test how well the atria work. But they take a long time to use, aren't accurate because they depend on the load, or are hard to copy because they depend on the observer. Also, some of their indices don't give a good enough picture of how the atrial reservoir works.[3,4]

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With the improvement of tissue doppler imaging, it is now possible to get a clear picture of the heart's structure and function no matter how hard it is working. The benefit of using Strain Rate and Strain imaging from tissue Doppler is that it is not affected by translational movements, so it accurately shows how the heart is changing shape. It was first used to measure localised changes in the shape of the ventricles.[5,6]

It has also been used to measure the function of the left atrium in people who have had Heart patients with hypertension and diabetes who have had cardiac resynchronization therapy. No one has previously studied the function of the left atrium when the mitral valve is narrow using strain and strain rate imaging.[7]

Tissue Doppler, Strain, and Strain Rate imaging were used to evaluate Left Atrial function in patients with severe Mitral Stenosis and healthy controls. As an additional finding,[8] the effects of balloon mitral valve surgery on atrial function were analysed.

Material and Methods

Study Design: From June 2021 to May 2022, a prospective descriptive trial was conducted.

Setting: 1000-bed hospital at Department of cardiology, Kamineni Academy of medical Sciences, LB nagar, Hyderabad, Telangana, India. Patients with moderate to severe Mitral Stenosis who were being treated in outpatient settings were enlisted. 50 patients with severe sinus-rhythm Mitral Stenosis and 50 matched controls.[9]

Inclusion Criteria

Control Group: Non-medicated patients without cardiovascular risk factors.

Mitral Stenosis Group: Balloon Mitral Valvotomy is proposed for patients with severe Mitral Stenosis and sinus

Exclusion Criteria

- Mitral stenosis sufferers who aren't good candidates for a balloon valvuloplasty
- Individuals who have been diagnosed with atrial fibrillation
- Those who have Aortic or Mitral regurgitation that is more severe than moderate
- Patients who require urgent Balloon Mitral
- Patients who had previously undergone heart surgery, such as a Closed Mitral Valvotomy.
- Patients who suffer from coronary artery disease, high blood pressure, and diabetes mellitus

Patients who had weak echo windows or whose studies were incomplete.

Clinical Assessment: All patients underwent a comprehensive evaluation consisting of a medical history interview, a physical examination, a 12-lead electrocardiogram, and a precordial 2D, M mode, and Doppler transthoracic echocardiographic examination. The function and deformation of the left atrium were studied using tissue Doppler velocities, strain, and strain rate imaging. Information was recorded and examined in detail.[10]

Echocardiographic and Doppler Studies: During expiratory apnea, transthoracic echocardiography and Tissue Doppler imaging with a 5 Hz probe on iE33 were performed on all subjects. Following ASEC guidelines, state-of-the-art instruments were used to measure all ventricular parameters. Left atrial diameters in millimetres, left ventricular internal dimensions in millimetres (LVIDDs and LVIDDd), interventricular septum thickness in millimetres (IVSd), and posterior wall thickness in millimetres (PWTd) at end diastole were all measured from M mode guided pictures in parasternal long axis view. There was a change made to the original Simpson LVEF formula. We calculated the MVA based on the pressure half-time and the planimetry. Valvular regurgitation can be detected using colour flow Doppler.[11,12]

The ejection fraction was determined using the modified Simpson's method, and the size and volume of the left atrium were estimated using 2D echocardiography in the apical 4 chamber

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view. The largest volume of the Left Atrium was recorded during ventricular systole with the mitral valve closed,[13] when the pulmonary veins and mitral apparatus were absent.

Pulse Waved Tissue Doppler Imaging: Tissue Doppler imaging was performed with the sample volume positioned at the interatrial septum and lateral left atrial wall in the apical four chamber view. We calculated the peak E' and A' velocities. This research took advantage of a high frame rate (above 110 fps). The interatrial septum was in the centre of the Doppler beam's focus. The Doppler frequency of the exhalation was measured. Aliasing was avoided in the data by using a velocity scale.[14]

The Imaging of Atrial Strain and Strain Rate: Images of the heart captured at >110 frames per second using small-sector colour Doppler were acquired (typically 30 degrees). Doppler beam strikes atrial wall at right angles. The volume of the sample was constrained by the thin walls of the atrium (10X2.5mm). Images were analysed for strain and strain rate using QLAB software for offline analysis. The interatrial septum and the lateral wall of the left atrium were chosen as the midpoint for the sample volume. Mean strain (strain and strain rate) measurements were collected at the R wave peak of end diastole and the T wave end of end systole.[15,16]

Mitral Valve Repair Using a Balloon and Aftercare: Trans-septal mitral valvotomy was performed on all patients with mitral stenosis. The treatment was effective if an echo indicated a mitral valve area more than 1.5 cm2 and mitral regurgitation less than 2+. Tissue Doppler velocities, strain, and strain rate were assessed,[17] 24 hours after balloon mitral valve replacement.

Statistical Analysis: SPSS for Windows 16.0 and RGui 2.8.0 are used for all statistical analyses (Chicago, USA). Calculations were performed using Mean and Standard Deviation. The Mann-Whitney U and student's t tests were used to compare the cases and controls. We used paired samples t tests and Wilcoxon signed-rank tests to compare outcomes before and after balloon mitral valvotomy. 0.05 It's 5%. Pearson The link between the two variables is determined by their correlation coefficient.[18]

Results

Fifty people with severe mitral stenosis (2D MVA= 0.90 0.17 cm2) and fifty age-matched controls (MS vs. Control, p= 0.30; 29.00 7.0 vs. 31.9 years) were studied. Left ventricular systolic, diastolic, and ejection fractions were all comparable between the two sets of participants [Table 1].

Table 1: Characteristics of the Baseline

Variable	**Controls (n=50)**	**Mitral stenosis (n=50)**	**p value**
Subject's Age	29.8 ± 9.8	29.6 ± 7.9	p = 0.39
Diastole M-mode LV dimensions (mm)	42.8 ± 2.7	38.8 ± 6.8	p = 0.15
Systole M mode LV (mm)	26.8 ± 3.6	25.9 ± 4.8	p = 0.22
M-mode wall measurements (mm)	8.3 ± 2.2	8.1 ± 2.1	p = 0.90
M mode IVS dimensions (mm)	8.2 ± 2.2	8.3 ± 2.2	p = 0.80
Simpson's LV EF (%)	62.1 ± 2.1	61.3 ± 4.8	p = 0.18
Peak TRGain (mm Hg)	16.3 ± 5.98 (n=36)	54.1 ±33.3 (n=50)	p <0.001
M-Mode RVD (mm)	8.2 ± 2.2	8.2 ± 2.0	p = 0.8

Mitral stenosis patients' 2D Left Atrial characteristics were compared to those of healthy controls'. Dimensions of the LA in M mode, the largest LA size in A4C, and the largest and smallest LA volumes were all bigger in patients with mitral stenosis. Patients with mitral

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stenosis showed a lower left ventricular (LA) ejection fraction than controls (24.4% vs. 59.3%; p0.001; MS vs Control).

Table 2: Diameters of the Left Atrial Echo

Variable	Controls (n=50)	Mitral Stenosis (n=50)	p value
LAD M Mode (mm)	28.2 ± 5.1	43.3 ± 6.5	p < 0.001
A4C max LA (mm)	44.5 ± 5.6	65.5 ± 7.0	p < 0.001
Maximum left atrial volume (ml)	34.3± 11.6	91.5 ± 32.2	p < 0.001
2 D LAV Max Volume (ml)	13.9 ± 5.8	68.8 ± 26.2	p < 0.001
Simpson's left atrial EF (%)	57.2 ± 7.7	24.3 ± 7.8	p < 0.001

In a tissue doppler study of left atrial function, individuals with mitral stenosis showed considerably lower E' and A' diastolic velocities compared to controls [Table 3].

Table 3: Indices of TDI

Variable	Controls (n=50)	Mitral Stenosis (n=50)	p value
IAS E' Velocity (cm/sec).	8.7 ± 3.8	7.8 ± 4.4	p = 0.002
IAS A' Velocity (cm/sec).	8.3 ± 8.8	6.2 ± 3.5	p = 0.01
Left atrial lateral wall E' velocity (cm/sec).	14.8 ± 5.2	7.5 ± 2.8	p <0.001
Left atrial lateral wall A' velocity (cm/sec).	12.2 ± 4.5	8.3 ± 1.8	p <0.001

End-systolic strain was lower in patients with mitral stenosis compared to controls at both the atrial septum (11.3 6.4%) and the left atrial lateral wall (19.2 9.0%) (p=0.004; MS vs. Control). Patients with mitral stenosis showed a decreased IAS Strain Rate at ventricular end diastole compared to controls (p=0.004). Other than Strain Abnormality, the features of the Systolic, Diastolic, and Strain Rate in [Table 4] demonstrate no significant differences between the two groups.

Table 4: Strain and Strain Rate parameters in MS as compared to controls

Variable	Controls (n=50)	Mitral Stenosis (n=50)	p value
VES IAS Strain (%)	28.5 ± 11.6	12.2 ± 5.3	p<0.001
IAS late diastolic strain (%)	-0.07 ± 0.45	0.06 ± 0.32	p = 0.4
End-systole IAS strain rate (per sec)	-0.14 ± 1.02	0.16 ± 0.86	p = 0.24
Late-diastolic IAS strain rate (per sec)	0.23 ± 0.56	-0.17 ± 0.34	p= 0.004
Left atrial wall strain at end-systole (%)	27.3 ± 14.1	19.3 ± 8.9	p= 0.004
Left atrial lateral wall strain at late diastole (%)	0.08 ± 0.62	0.02 ± 0.57	p = 0.7
Left atrial wall strain at end systole (per sec)	0.35 ± 0.72	0.16 ± 0.62	p = 0.3
Left atrial late diastolic strain rate (per sec)	0.12 ± 0.5	-0.14 ± 0.47	p=0.06

Based on palnimetric evaluation, all of the Mitral Stenosis patients in the study had effective BMV, with a 2D mean Mitral Valve area of 2.00 0.200 cm2. The maximum and lowest LA volumes and M mode LA dimensions were both smaller after BMV than they had been before. A4C measurements showed no difference in LA size before and after treatment (65.00 9.1 mm vs. 63.3 7.3 mm; p=0.06: before versus after).

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Table 5: Parameters of echo- and doppler-sound waves before and after a brain-machine interface

Variable	Pre BMV (n=50)	Post BMV (n=50)	p value
LAD M Mode (mm)	43.6 ± 6.5	36.2 ± 6.7	p=0.001
A4C max LA (mm)	63.5±7.2	62.3± 7.4	p=0.07
Maximum left atrial volume (ml)	91.7± 30.2	69.8±27.8	p<0.001
2D Minimum Left Atrial Volume	68.9±26.2	49.3±18.9	p<0.001
Simpson's left atrial EF (%)	24.3±7.2	33.8±10.1	p<0.001
Mitral Valve 2D (cm2)	0.90±0.15	1.93±0.26	p<0.001
Mitral Doppler (cm2)	0.90±0.16	1.9±0.24	p<0.001
TR Gradient Doppler (mmHg)	54.2±35.2	30.8±16.3	p<0.001

The Tissue Doppler velocity at the interatrial septum did not change after BMV, while the E' velocity at the lateral wall did (7.00 2.00 vs 9.00 2.1; p0.001: Pre BMV vs Post BMV).

Table 6: Tissue Doppler Velocities Pre and Post BMV

Variables	Pre BMV (n=50)	Post BMV (n=50)	p value
IAS E' Velocity (cm/sec).	7.8 ± 2.6	5.6 ± 3.7	p=0.80
IAS A' Velocity (cm/sec).	8.2 ± 1.5	7.7 ± 1.3	p=0.50
Left atrial lateral wall E' velocity (cm/sec).	7.5 ± 1.8	9.9 ± 1.2	p<0.001
Left atrial lateral wall A' velocity (cm/sec).	8.5 ± 1.8	6.4 ± 3.5	p=0.80

The left atrial IAS systolic strain improved after balloon mitral valve replacement (12.4 5.3% vs 19.0 11.6%; p=0.021), while the lateral wall systolic strain showed some improvement (19.0 9.8% vs 20.8 19.6; p=0.07).
The strain rate of the lateral atrial wall at the end of systole was lower after BMV therapy compared to baseline measurements. All other systolic and diastolic strain and strain rate characteristics in [Table 7] were similar to pre-BMV levels.

Table 7: Strain and strain rate parameters Pre and Post BMV

Variables	Pre BMV (n=50)	Post BMV (n=50)	p value
VES IAS Strain (%)	11.5 ± 6.4	18.4 ± 10.2	p=0.02
IAS late diastolic strain (%)	0.06 ± 0.32	0.15 ± 0.85	p=0.70
End-systole IAS strain rate (per sec)	0.12 ± 0.84	0.25±0.48	p=0.70
Late-diastolic IAS strain rate (per sec)	-0.14 ±0.37	-0.18± 0.68	p=0.90
Left atrial wall strain at end-systole (%)	18.3 ± 8.6	22.8 ± 10.5	p=0.07
(%) Left atrial lateral wall strain at ventricle late diastole	0.016 ± 0.58	-0.15 ± 1.05	p=0.50
Left atrial wall strain at end systole (per sec)	0.16 ± 0.62	-0.23 ± 0.65	p=0.02
Left atrial late diastolic strain rate (per sec)	-0.12 ± 0.48	0.003 ± 0.6	p=0.40

Left atrial Systolic Strain measured at the atrial septum was negatively correlated with maximal left atrial volume (p0.001, R=-0.06). Maximum LA volume and left atrial Lateral wall Systolic Strain was correlated (p0.001, R= -0.50).

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 08, 2022

DISCUSSION

For the first time, researchers in India have used Tissue Doppler and Strain imaging to examine how balloon mitral valve replacement affects Left Atrial function. Myocardial reservoir function, as measured by left atrial tissue Doppler velocity and systolic strain are aberrant in mitral stenosis; however, strain levels normalise after 24 hours of BMV.[19] The left atrial function is influenced by both ventricular and atrial variables. Impairments to left atrial function can result from anomalies in contractility, relaxation, pressure, compliance, and rhythm. Annular motion, compliance, and relaxation are all factors in the left ventricle. A dilated and remodelled left atrium is associated with mitral stenosis. The atrium swells in response to elevated blood pressure and heart volume. The left atrial (LA) pressure with rheumatic mitral stenosis varies greatly due to LA compliance, even though the Mitral valve area is constant. Despite having a similar Mitral Valve area, patients with rheumatic mitral stenosis show varying degrees of left atrial stiffness.[20,21]

Atrial fibrillation and intraatrial stasis with strong spontaneous contrast have been linked to abnormally rigid left atrial walls. Our results showed that the maximum and minimum left atrial volumes were larger in the mitral stenosis group compared to the Control group. Due to increased mitral valve resistance, the left atrium enlarges in patients with mitral stenosis. Left Atrial pump function may be impaired by increased afterload (at mitral valve level) during atrial contraction.[22,23]

Using 3D echo, Miseung Shin et al. discovered that 44 patients with mitral stenosis had a decreased Left Atrial ejection percentage compared to age-matched controls. When the mitral valve is repaired using a balloon, the area of the valve is increased, which in turn decreases afterload and boosts the ejection fraction of the left atrium. This was discovered in our research 24 hours after balloon mitral valve surgery. Having atrial arrhythmias is a symptom of mitral stenosis. Around 30%-40% of people with mitral stenosis also have atrial fibrillation. Assessing atrial function in patients with mitral stenosis is essential for establishing a prognosis. In the past, measuring atrial function has been challenging or inaccurate. Quickly estimating atrial size via M mode along the parasternal long axis. Since the left atrium can enlarge in directions than the vertical,[24,25] it is not always accurate. Atrial reservoir, conduit, and contractile function can be assessed using tissue Doppler imaging with offline Strain measurement. The capacity of the left atrial reservoir, conduit, and pump is evaluated based on peak systolic values. This is a brand novel approach of evaluating atrial function in patients with severe mitral stenosis. We measured reservoir function by the mean Strain at the end of systole, and found that patients with severe mitral stenosis had lower reservoir function. This was visible in the centre of the mid-interatrial septum and the mid-lateral LA wall. Both the interatrial septal strain and the systolic strain at the lateral LA wall improved within 24 hours post balloon mitral valve surgery. The 24-hour change in left atrial size as assessed by A4C after balloon mitral valve surgery was not statistically significant. Indicating that these issues are functional and associated with mitral stenosis rather than structural.[26,27]

In patients with lone AF, peak atrial systolic strain is a reliable indication of sinus rhythm stability. Patients who relapsed into AF following cardioversion had reduced Systolic Strain in the inferior LA wall and atrial septum. Therefore, if the systolic strain of patients with severe mitral stenosis decreases after balloon mitral valve surgery.[28,29] they may be able to maintain sinus rhythm and experience fewer cardiovascular events. Left atrial volume, rather than left atrial dimensions, was found to be a better predictor of future atrial fibrillation and other cardiovascular events in a number of clinical populations studied by Tsang et al. Maximum left atrial volume and systolic strain correlated negatively in patients with severe mitral stenosis. Metrics based on strain are useful for assessing Left Atrial remodelling and making Atrial Fibrillation forecasts. When the atrioventricular (AV) valve is closed, the atria

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 08, 2022

collect blood for later use during ventricular systole. Its performance may be influenced by atrial stiffness, atrial relaxation, and ventricular contraction via base descent. Peak systolic strain in the atria has been shown to correlate strongly with peak systolic flow in the pulmonary veins, suggesting that it may be a valid indicator of atrial reservoir function. There is a slight correlation between peak systolic atrial strain and ventricular pressure.[30,31] There is no connection between atrial peak systolic deformation and peak systolic AV ring displacement. These findings provide support for the hypothesis that differences in atrial myocardial compliance cause abnormal atrial deformation during this period, and imply that tethering effects and global heart motion have less of an impact on peak systolic atrial Strain and Strain Rate.

Diastolic atrial deformation was not significantly different between patients with mitral stenosis and controls in our investigation. At the time of diastole, when the mitral valve is open, LV compliance may have an effect on left atrial function.[32]

Peak early diastolic strain was shown to correlate with peak Systolic annular excursion, and early diastolic strain and strain rate values were shown to correlate with markers of left ventricular (LV) global diastolic function in a study by Di Salvo et al. One possible explanation for the absence of irregularities is that diastolic measures are less repeatable than systolic ones, as has been reported in previous studies. Due to low repeatability and the fact that left atrial contractile activity is dependent on non-myocardial variables, diastolic strain tests may not be useful for diagnosing atrial dysfunction. Maybe this is why we didn't look for signs of contractile failure by measuring diastolic strain. When it comes to predicting atrial fibrillation and cardiovascular events, systolic atrial myocardial deformation features are more accurate than diastolic measures.[33,34]

Those with severe mitral stenosis have slower diastolic velocities in the atrial septum and left atrial lateral wall compared to those without the condition.[35]

Peak systolic and late diastolic velocities in all tissues except the septum were lower in patients with moderate to severe mitral stenosis compared to controls. Septal velocities were also lower in patients with mitral stenosis. Extreme mitral stenosis,[36] among the participants might be to blame. All of our patients, unlike the ones studied by Mi Seung Shin et al., had significant mitral stenosis, which may have accounted for the more extreme left atrial dysfunction and aberrant septal tissue Doppler velocities we observed. The early diastolic Tissue Doppler velocity of the lateral LA wall rose after balloon mitral valve surgery, but the velocity of the interatrial septum remained unchanged. This may be explained by the interatrial septum's denser structure. As a result of BMV, the lateral wall velocity is increased after an abrupt decrease in left atrial after load.[37]

CONCLUSION

Our results prove that imaging Tissue Doppler velocities and Tissue Doppler derived Strain can be used to evaluate left atrial function. In individuals with severe mitral stenosis, it can be used to assess the degree of atrial reservoir function degradation. The maximal volume of the lateral anterior descending artery (LA) is a sensitive predictor of cardiovascular events and is linked with the severity of impairment. Within 24 hours of treatment, these anomalies are frequently normal again after balloon mitral valvotomy. These biomarkers may help evaluate prognosis and identify people at risk for disorders like AF, and it is thought that they can predict cardiovascular events. Therefore, these data may help doctors decide on the best course of treatment for these patients in the future.

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