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Correlation of Invasive Left Atrial Pressure and Mitral Valve Area in Rheumatic Mitral Stenosis: A Cross-Sectional Study

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Highlights

- Mean left atrial pressure (LAP) measured invasively correlates with mitral valve area (MVA) assessed by 3D-TEE in patients with severe rheumatic mitral stenosis.
- Patients with MVA<1 cm² had significantly higher LAP and echocardiography-derived pulmonary artery pressures than those with MVA≥1 cm².

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ABSTRACT

Background: Mitral stenosis (MS) is typically assessed using both echocardiographic and invasive methods, which are critical for treatment planning. The present study analyzed the correlation between invasively measured left atrial pressure (LAP) and mitral valve area (MVA) assessed by three-dimensional transesophageal echocardiography (3D-TEE) in patients with rheumatic MS undergoing percutaneous transluminal mitral commissurotomy (PTMC).

Methods: We conducted a cross-sectional study of 135 patients with severe rheumatic MS who were candidates for PTMC at Shahid Madani Heart Hospital, Tabriz, Iran, between April 2023 and April 2024. All patients underwent two-dimensional transthoracic echocardiography (2D-TTE) and 3D-TEE for MVA measurement. Invasive LAP and pulmonary pressures were recorded pre-procedure. Comparisons were made between patients with MVA<1 cm² and those with MVA≥1 cm².

Results: The mean MVA measured by 3D-TEE was 1.03±0.07 cm². LAP was significantly higher in patients with MVA<1 cm² than in those with MVA≥1 cm² (P=0.040). Pulmonary artery pressures also differed significantly between the groups (P=0.016 and P=0.012). Among the 135 participants, 109 patients (63.3% with MVA<1 cm² and 93.6% with LAP>15 mm Hg) reported dyspnea, while 20 patients (65% with MVA<1 cm² and 100% with LAP>15 mm Hg) reported fatigue.

Conclusions: In this study, we observed a significant correlation between invasive LAP and MVA measured by 3D-TEE. These findings suggest that invasive LAP measurement offers additional value in assessing the hemodynamic burden of severe MS.

Keywords: Mitral Valve Stenosis; Left Atrial Pressure; Mitral Valve Area; Echocardiography

Introduction

Cardiovascular diseases, particularly those involving valvular abnormalities, remain a leading cause of morbidity and mortality worldwide.[1] Among these, mitral valve (MV) disease-encompassing a spectrum of disorders affecting the MV's structure and function—is of particular interest due to its prevalence and significant impact on patient outcomes.[2] Most patients with mitral stenosis (MS) eventually develop symptoms requiring aggressive treatment, including balloon mitral valvotomy (BMV) or surgical interventions such as MV replacement or repair.[3]

Currently, decisions regarding the need for invasive procedures to treat MV stenosis are primarily based on mitral valve area (MVA) and the presence of clinical symptoms.[4] Among these parameters, left atrial pressure (LAP) is particularly important as it determines symptom severity and plays a crucial role in predicting patient outcomes following interventions such as BMV or surgery.[5] LAP is typically measured through invasive methods, including cardiac catheterization, which can assess pressure directly via a transseptal approach or indirectly through pulmonary capillary wedge pressure (PCWP) measurement.[6,7]

The use of noninvasive methods has gained increasing importance in clinical practice due to their accessibility and favorable risk profile. Two-dimensional echocardiography (2D-echo) techniques—including pressure half-time, proximal is velocity surface area, and planimetry—are commonly used to estimate MVA.[8] Nonetheless, these methods are often limited by geometric assumptions about valve anatomy that may compromise accuracy. Recent advances in three-dimensional transesophageal echocardiography (3D-TEE) enable more precise and comprehensive evaluation of MV morphology and surface area.[9]

Studies demonstrate that 3D-TEE planimetry-derived MVA measurements show strong correlation with invasive measurements obtained using the Gorlin formula, presenting a promising noninvasive alternative.[8-10] Bleakley et al.[11] (2018) compared 3D and 2D echo in 41 MS patients, finding that the 3D approach yielded significantly smaller valve area measurements. This enhanced precision facilitated more accurate disease staging and improved treatment decisions.

The 3D-TEE method provides more accurate MVA measurements while enabling comprehensive evaluation of valve morphology, including assessment of commissural fusion severity and detection of left atrial thrombi.[12] This technique can be performed concurrently with catheterization procedures or surgery, delivering real-time data to guide therapeutic decision-making.[13]

Despite these advancements, MVA assessment using different modalities remains challenging, particularly when discrepancies occur between invasive and noninvasive measurements.[7,14] Precise grading of MV stenosis is crucial for determining optimal treatment strategies, highlighting the need for continued research in this field. Our study examined the correlation between invasively measured mean LAP and 3D echocardiographic planimetry-derived MVA.

Methods

Study design and participants

This cross-sectional, observational analysis was conducted at Shahid Madani Heart Hospital, the primary tertiary cardiovascular center in Tabriz, Iran. The study aimed to investigate the correlation between mean LAP acquired through invasive methods and MVA measured using 3D-echo planimetry in patients with severe MS who were candidates for PTMC.

The study protocol received approval from the Institutional Review Board and Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1402.093). Participant recruitment occurred between April 2023 and April 2024. Eligible patients were aged 18 to 80 years, had rheumatic MS defined by MVA≤1.5 cm², and were initially considered for PTMC.

Exclusion criteria included a history of PTMC within the previous month, contraindications to TEE, such as esophageal disorders, LA or LA appendage thrombus presence, or progressive MS

(MVA>1.5 cm²) as identified by 3D planimetry.

Echocardiographic assessments

Two-dimensional transthoracic echocardiography (2D-TTE)

All 2D-TTE examinations were performed using a Philips EPIQ 7C ultrasound system equipped with an X5-1 matrix transducer (Philips, Netherlands). MVA was measured via direct planimetry, with the operator optimizing imaging settings to visualize the smallest MV orifice at the leaflet tips in the parasternal short-axis view during mid-diastole at maximal valve opening.[15]

Standard measurements included transmitral mean pressure gradient, peak mitral flow velocity, mitral regurgitation (MR) severity graded according to the American Society of Echocardiography guidelines,[16] left ventricular ejection fraction, left atrial volume index (LAVI), and pulmonary artery systolic pressure (PASP) derived from the tricuspid regurgitation peak gradient.

A comprehensive evaluation of concomitant valvular pathology was performed, including assessments of aortic, tricuspid, and pulmonary valve function for regurgitation or stenosis.

3D-TEE

3D-TEE was performed using a real-time matrix-array transducer (2-7 MHz) on the Philips EPIQ 7C ultrasound system. Following optimization of gain settings, compression controls, and time-gain compensation, 3D Zoom datasets were acquired at four standard imaging angles (0°, 45°, 75°, and 120°) for patients in sinus rhythm. For patients with atrial fibrillation, single-beat acquisition was utilized, and images demonstrating stitch artifacts during subsequent analysis were excluded.

The MV surface was reconstructed in 3D after obtaining an optimal bi-commissural view using 3D Zoom mode, with all images digitally archived for offline processing. With the aid of QLAB software, the stored images were analyzed to generate appropriate 3D MV reconstructions. MVA was calculated through 3D multiplanar reconstruction planimetry, and the measurements were used to determine stenosis severity.

Investigator bias was minimized by having all measurements independently performed by two experienced echocardiologists who were blinded to each other's results. Interobserver agreement was subsequently calculated using kappa statistics, and discrepancies were resolved through consensus review.

Hemodynamic measurements

Following echocardiographic assessment, patients underwent invasive hemodynamic evaluation in the catheterization laboratory prior to PTMC. LAP and pulmonary artery pressures were measured directly using standard catheterization techniques. To calculate the mean pulmonary artery pressure, we multiplied systolic pressure by 2 and, then, added the diastolic pressure to the result. Afterward, we divided the sum by 3 to obtain the mean pulmonary artery pressure.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 21.0; IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test assessed the distribution normality of continuous variables. Continuous variables are expressed as mean±standard deviation, while categorical variables are presented as frequencies and percentages. Independent samples t-tests compared continuous variables, and chi-square tests analyzed categorical data. A P-value<0.05 was considered statistically significant.

Results

(Table 1) presents the baseline characteristics of the study participants, including key echocardiographic and hemodynamic parameters. The cohort demonstrated a mean age of 64.67±10.63 years with a female predominance (71%). Atrial fibrillation was present in 32.6% of patients, and 15.6% had prior PTMC history. Dyspnea symptoms were reported by 80.7% of participants.

Echocardiographic measurements showed a

mean MVA of 1.03±0.07 cm², with mitral gradients and velocities within expected ranges. The mean PASP was 38.06±10.90 mm Hg, and the mean LAVI measured 67.54±21.53 mL/m². Hemodynamic evaluation revealed a mean pulmonary artery pressure of 32.78±8.64 mm Hg, a mean PASP of 50.85±12.60 mm Hg, and a mean LAP of 26.20±6.08 mm Hg.

(Table 2) presents the comparison of echocardiographic and hemodynamic parameters stratified by MVA. No significant differences were observed between patients with MVA<1 cm² and those with MVA≥1 cm² in mean mitral gradient (P=0.92), peak mitral gradient (P=0.38), peak mitral velocity (P=0.31), or LAVI (P=0.51).

Significant differences emerged in PASP measured by echocardiography (P=0.016), mean pulmonary artery pressure (P=0.012), and LAP (P=0.040), with higher values observed in the MVA<1 cm² group. In contrast, catheterization-measured PASP showed no significant between-group differences (P=0.975).

Among the 135 participants, 109 reported dyspnea, with 69 patients (63.3%) having MVA<1 cm² and 40 patients (36.7%) having MVA≥1 cm². Of these dyspneic patients, 7 (6.4%) demonstrated LAP≤15 mm Hg while 102 (93.6%) showed LAP >15 mm Hg. Fatigue symptoms were reported by 20 patients, with 13 cases (65%) occurring in the MVA<1 cm² group and 7 cases (35%) in the MVA≥1 cm² group. Notably, all fatigued patients exhibited LAP>15 mm Hg, while no cases were observed at LAP≤15 mm Hg.

(Table 3) illustrates the relationship between age, echocardiographic parameters, and LAP values stratified by LAP>15 mm Hg versus LAP≤15 mm Hg. Patients with LAP>15 mm Hg showed significantly higher values for mean gradient (P=0.046), peak gradient (P=0.029), and peak velocity (P=0.013) than those with LAP ≤15 mm Hg.

No significant differences were observed between groups for LAVI (P=0.32), echocardiography-derived PASP (P=0.14), MVA (P=0.77), or catheterization-measured PASP (P=0.448).

Table 1. Baseline Characteristics and Key Echocardiographic and Hemodynamic Parameters

Variable	Value
Number of Subjects	135
Age (mean ± SD)	64.67 ± 10.63 years
Female / Male ratio	97 (71%) / 38 (29%)
Atrial Fibrillation	44 (32.6%)
History of PTMC	21 (15.6%)
Dyspnea	109 (80.7%)
MVA (3D TEE)	1.03 ± 0.07 cm²
Mean Mitral Gradient	8.37 ± 4.41 mmHg
Peak Mitral Gradient	15.58 ± 6.46 mmHg
Peak Mitral Velocity	1.90 ± 0.36 m/s
Pulmonary Artery Systolic Pressure (echo)	38.06 ± 10.90 mmHg
Left Atrial Volume Index (LAVI)	67.54 ± 21.53 ml/m²
Left Ventricular Ejection Fraction (LVEF)	54.32 ± 2.58
Left Ventricular End-Systolic Diameter (LVESD)	30.68 ± 4.32 mm
Left Ventricular End-Diastolic Diameter (LVEDD)	45.55 ± 3.56 mm
Mean Pulmonary Artery Pressure (Hemodynamic Study)	32.78 ± 8.64 mmHg
Pulmonary Artery Systolic Pressure (Hemodynamic Study)	50.85 ± 12.60 mmHg
Left Atrial Pressure (Hemodynamic Study)	26.20 ± 6.08 mmHg

Table 2. Comparison of Echocardiographic and Hemodynamic Parameters Relative to Mitral Valve Area (MVA)

Parameter	MVA < 1 cm²	MVA ≥ 1 cm²	P Value
Mean Mitral Gradient (mmHg)	8.94 ± 4.84	8.02 ± 4.11	0.92
Peak Mitral Gradient (mmHg)	16.20 ± 6.66	15.20 ± 6.35	0.38
Peak Mitral Velocity (m/s)	1.94 ± 0.40	1.88 ± 0.32	0.31
LAVI (ml/m²)	69.11 ± 22.01	66.59 ± 21.31	0.51
Pulmonary Artery Systolic Pressure (Echo, mmHg)	40.95 ± 14.64	36.31 ± 7.38	0.016
Pulmonary Artery Systolic Pressure (Cath, mmHg)	50.62 ± 11.61	50.55 ± 13.20	0.975
Pulmonary Artery Mean Pressure (mmHg)	35.15 ± 8.69	31.34 ± 8.33	0.012
Left Atrial Pressure (mmHg)	27.57 ± 6.88	25.36 ± 5.40	0.040

Table 3. Comparison of Hemodynamic and Echocardiographic Parameters Based on Left Atrial Pressure (LAP) Categories

Parameter	LAP ≤ 15 mmHg (Mean ± SD)	LAP > 15 mmHg (Mean ± SD)	P Value
Mean Gradient (mmHg)	5.36 ± 1.75	8.56 ± 4.64	0.046
Peak Gradient (mmHg)	10.75 ± 4.71	15.88 ± 6.45	0.029
Peak Velocity (mmHg)	1.60 ± 0.32	1.92 ± 0.35	0.013
Left Atrial Volume Index (LAVI) (ml/m²)	67.08 ± 18.52	74.87 ± 51.32	0.32
Pulmonary Artery Systolic Pressure (Echo) (mmHg)	32.62 ± 6.90	38.41 ± 11.03	0.14
Mitral Valve Area (MVA) (3D) (cm²)	1.04 ± 0.88	1.05 ± 0.98	0.77
Pulmonary Artery Systolic Pressure (Cath) (mmHg)	53.87 ± 10.94	50.37 ± 12.71	0.448

Discussion

The primary objective of this study was to investigate the relationship between invasively measured LAP and MVA as assessed by 3D-TEE in patients with MS. Our findings demonstrated no significant difference in mean MV gradients between patients with an MVA<1 cm² and those with an MVA between 1 and 1.5 cm². These results chime with previous studies, which suggest that MV gradients alone may be insufficient to distinguish between different levels of MS severity, particularly when MVA is near the intervention threshold.[14,16]

Although MV gradients are helpful in assessing the severity of MS, they may not fully capture the hemodynamic compromise, particularly in patients with mild-to-moderate stenosis where other factors could have significant influence.[14,17,18] On the other hand, PASP, as measured by echocardiography, exhibited a significant difference between the two groups, which underscores its importance in MS assessment.

Elevated PASP levels indicate increased LAP and consequent pulmonary hypertension, which often occurs in severe MS cases.[19] Thus, while MVA offers a direct measure of valve obstruction, PASP serves as a crucial complementary parameter reflecting the hemodynamic effects of MS.[19,20]

The ability of PASP to differentiate between MVA categories indicates that echocardiographic assessments of pulmonary artery pressure can improve the evaluation of MS severity. This is particularly significant in clinical settings where accurate disease severity stratification is essential for determining the most suitable therapeutic interventions.[21] For instance, in cases where MVA is marginally below the surgical threshold of 1.5 cm², PASP measurements can offer additional information that may impact management decisions. In a study of 436 patients with rheumatic MS, rapid PASP progression was linked to worse outcomes, suggesting that elevated PASP serves as a marker of more severe disease and higher risk.[19] These findings highlight the role of PASP as both a marker of current disease severity and a predictor of disease progression and patient outcomes.

Another significant finding was the notable correlation between LAP and MV gradients, particularly in patients with LAP>15 mm Hg. This correlation reinforces the role of echocardiographic mitral gradients as an estimator of LAP, which is crucial in assessing the hemodynamic burden in patients with severe MS. Our data demonstrated that a mitral gradient ≤5 mm Hg was generally associated with LAP≤15 mm Hg, suggesting that lower mitral gradients could predict lower LAP, particularly in patients with smaller body surface areas. These findings are concordant with existing literature, which has shown that LAP is a key determinant of symptom severity and disease progression in MS.[15,22,23]

In MS, LAP rises due to a reduction in MVA, increased mean diastolic pressure gradient, and decreased LA compliance. These factors collectively contribute to the hemodynamic burden in MS.[5] These findings underscore the significance of assessing LAP and mitral gradients in evaluating disease severity and progression. Combining echocardiographic parameters, such as PASP and mitral gradients, with invasive LAP measurements can improve the accuracy of MS severity assessment.[24] This comprehensive approach can lead to more appropriate and timely interventions, which could improve patient outcomes.[20]

The current study's single-center design may limit the generalizability of the results to other clinical settings or patient populations with distinct clinical characteristics. Another limitation is the dependence on echocardiographic measurements, which, despite being accurate, can be operator-dependent and introduce variability in MVA and pulmonary pressure assessments.

While we employed 3D-TEE for MVA measurement, which is considered more precise than 2D methods, the accessibility and proficiency in using 3D-TEE may differ across institutions, possibly affecting the reproducibility of our findings.

Conclusion

In conclusion, while MV gradients are routinely used to evaluate MS severity, our study demonstrates that they may not consistently differentiate between varying degrees of stenosis in patients with severe or moderate-to-severe MS (MVA<1.5 cm^2). This highlights the significance of incorporating PASP measurements, which exhibited significant differences among patients with various MVA values.

Elevated PASP levels, indicative of increased LAP and pulmonary hypertension, serve as a critical complementary indicator in assessing the hemodynamic burden of MS. Furthermore, the observed correlation between mitral gradients and LAP emphasizes the role of these gradients as estimators for LAP, particularly in severe MS cases.

Combining PASP, mitral gradients, and LAP measurements improves the overall evaluation of MS severity, informing clinical decisions about timely interventions.

Declarations:

Ethical Approval

The study protocol was approved by the institutional review board and ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1402.093).

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Conflict of Interest

Authors declare no conflict of interests.

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