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Assessment of Post-Procedural Mitral Regurgitation and Its Mechanisms Using 3D Transthoracic Echocardiography Following PMBC in Patients with Rheumatic Mitral Stenosis

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ABSTRACT

Background: Rheumatic mitral stenosis (MS) remains a significant cardiovascular burden in low- and middle-income countries (LMICs). Percutaneous mitral balloon commissurotomy (PMBC) is the standard intervention, but mitral regurgitation (MR) remains a major complication. **Objectives:** This study aimed to determine the incidence, severity, and underlying mechanisms of MR following PMBC using three-dimensional transthoracic echocardiography (3D TTE). **Methods:** In this prospective study, 300 patients with severe symptomatic rheumatic MS underwent PMBC from September, 2023 to December, 2024. Baseline and post-procedural echocardiographic assessments were performed, and mechanisms of MR were classified using 3D TTE. **Results:** New or worsening MR occurred in 41% of patients post-PMBC. MR was mild in 16%, moderate in 15%, and severe in 10% of cases. Commissural MR was the most common mechanism of significant MR (32%), followed by commissural MR with posterior leaflet involvement (26%) and central MR (17%). Leaflet tear involving the central scallops accounted for 10 of the 32 severe MR cases. **Conclusions:** MR is a frequent complication following PMBC, with distinct mechanistic patterns identifiable via 3D TTE. Understanding these mechanisms may inform clinical decision-making and long-term clinical outcomes.

INTRODUCTION

Rheumatic heart disease (RHD) affects approximately 33.4 million people globally[1], with mitral stenosis (MS) being its predominant manifestation accounting for 2 to 14 percent[2] of its total burden.

Rheumatic mitral stenosis is prevalent among LMICs that are endemic for group A streptococcus pharyngitis and acute rheumatic fever (prevalence in Pakistan being 22/1000 population[3] with patients presenting with symptoms in second to fourth decade of life.

The primary pathological feature of MS is commissural fusion of the mitral valve, accompanied by leaflet thickening, retraction, and varying degrees of calcification. The subvalvular apparatus is often involved, resulting in chordal shortening and fusion. Percutaneous mitral balloon commissurotomy (PMBC) has become the standard management for suitable valves, depending on valve morphology. The suitability of a valve for PMBC can be determined using the Wilkins score: a morphologic score or other recently devised scores to determine long term risk[4]. Concomitant MR and its severity influence the choice of procedure.

In patients with favorable morphology PMBC has success rates >90% and up to 75% in recent studies with increasing sub optimal valve morphology[5].

However, post-procedural MR, particularly moderate to severe MR, remains a significant complication. Mild MR or worsening MR has been reported in unto 20 %of patients in a series[6].Moderate or severe MR occurs in 8.4% to 20% of cases [7], and severe MR in most series is <10%. Three-dimensional transthoracic echocardiography (3D TTE) offers a detailed, real-time assessment of the mitral valve, allowing for precise identification of MR mechanisms[8]. Most frequently MR is due to commissural splitting and causes central regurgitation. Excessive commissural splitting with or without laceration of commissural scallops may result in one or more eccentric jets of MR termed commissural MR. It may include leaflet tear at posterior P1 and P3 scallops or central scallop A2 P2 and para commissural leaflet detachment from the annulus and chordal rupture leading to flail motion of the leaflets and significant MR.

Kaul et al[7] reported an 8.4% rate of significant MR in series of over 3000 patients. Leaflet tear was the mechanism in

severe MR (73%) and commissural splitting in moderate MR (64%)

Kim et al 10 reported commissural splitting as the mechanism in 57%, chordal rupture in 26%, and leaflet laceration in 17% of cases.

This study aimed to determine the incidence and severity of MR following PMBC and to evaluate the underlying mechanisusing 3D TTE.

MATERIALS AND METHODS

Study Population

A total of 300 patients with symptomatic severe rheumatic MS undergoing PMBC at the Armed Forces Institute of Cardiology (AFIC) from September, 2023 to December, 2024 were prospectively enrolled. All participants provided written informed consent.

Pre-Procedural Assessment

Comprehensive 2D transthoracic and transesophageal echocardiography (TTE/TEE) was performed. Mitral valve area (MVA) was calculated using planimetry, with MVA <1.5 cm^2 defining severe MS. Mean transmitral gradients and pulmonary artery systolic pressure (PASP) were measured via Doppler echocardiography. The Wilkins score was used to assess valve morphology, with a score <8 indicating suitability for PMBC. MR was quantified using color and continuous wave Dopple Effective orifice area mild MR< 0.2 cm^2moderate MR: 0.2–0.39 cm^2 severe MR: ≥ 0.4 cm according to guidelines 11.LA/LAA thrombus was ruled out via TEE.

PMBC Procedure

PMBC was performed using the anterograde transseptal approach with the Inoue balloon technique. A successful procedure was defined as post-procedure MVA ≥1.5 cm^2 and MR less than grade III, with no major in-hospital cardiac or cerebrovascular events.

Post-Procedural Assessment

Repeat 2D TTE was performed immediately post-PMBC to assess MVA, MR severity, and commissural splitting. MR severity was graded per guidelines using effective regurgitant orifice area (EROA): mild (<0.2 cm^2), moderate (0.2–0.39 cm^2), and severe (≥0.4 cm^2).

3D Echocardiographic Analysis

3D TTE was used to identify MR mechanisms using full-volume and zoom-mode imaging. Central MR was defined by the absence of structural damage[12]. Commissural MR was classified by regurgitant jet origin the site of split anterolateral or posteromedial commissure.

In commissural MR involving the posterior leaflet, the regurgitant jet appears at the anterolateral commissure and extending into scallop P1 or at the posteromedial commissure extending into scallop P3.

MR at central scallop location (A2/P2) is regurgitant jet at central scallop of anterior and posterior leaflet and or leaflet laceration and subvalvular damage that results in chordae rupture and flail motion of the leaflets.

Statistical Analysis

Descriptive statistics were used to summarize baseline demographic and clinical characteristics of the study population.

Continuous variables were expressed as mean ± SD or median (IQR) and compared using Student's t-test or Mann-Whitney U test. Categorical variables were compared using chi-square or Fisher's exact test. The primary outcome, the frequency and severity of MR were classified into three categories: mild, moderate and severe.

A p-value <0.05 was considered statistically significant.

RESULTS

Table 1

Demographics and Baseline Characteristics

Variable	Value
Mean age (years)	37.2 ± 10.2
Female (%)	210 (70%)
NYHA Class III–IV (%)	165 (55%)
Atrial fibrillation (%)	183 (61%)
Benzathine penicillin use (%)	243 (81%)
Anticoagulation use (%)	195 (65%)
Previous PMBC (%)	30 (10%)
Embolic stroke/TIA (%)	36 (12%)

Table 2

Baseline Echocardiographic Parameters

Parameter	Value
LVEDD (mm)	43.5 ± 5.9
LVEF (%)	60.1 ± 6.9
LA diameter (mm)	48.1 ± 6.5
MVA (cm^2)	0.92 ± 0.25
Mean mitral gradient (mmHg)	11.1 ± 4.5
PASP (mmHg)	50.1 ± 2.5
Significant TR (%)	75 (25%)
Mild MR (%)	75 (25%)
Wilkins score (median, IQR)	7 (6–8)

Table 3

Post-PMBC Echocardiographic Parameters

Parameter	Value
MVA (cm^2)	1.68 ± 0.24
Mean mitral gradient (mmHg)	6.5 ± 2.2
PASP (mmHg)	40.2 ± 5.5
Commissural splitting (%)	225 (75%)
New mild MR (%)	48 (16%)
Moderate MR (%)	43 (15%)
Severe MR (%)	32 (10%)

Table 4

Mechanisms of Significant MR (3D TTE)

MR Mechanism	Mild	Moderate	Severe
Central MR	30	11	3
Commissural MR	15	16	8
Commissural MR + posterior leaflet	3	9	11
Central scallop / chordal rupture	0	7	10

DISCUSSION

With advancement in local experience and expertise in PMBC for rheumatic mitral stenosis this study aimed to analyze frequency, severity and mechanism of post procedural mitral regurgitation as a major procedure related complication.

In our study new or worsening Mitral regurgitation on 2 D transthoracic quantitative analysis after PMBC is a frequent complication occurring in up-to% 41 patients. MR was mild in up to 16 % of cases closely followed up by moderate MR (15%) and up to 10 % patients developed severe MR.

3D TTE provided detailed insight into MR mechanisms. Central MR is usually mild in severity and is identified as mechanism of significant MR in 17 %patients. commissural MR is the most frequent (32%) mechanism identified in significant mitral regurgitation with commissural with posterior leaflet involvement is the mechanism of significant MR in 26% patients. Of patients developing severe MR, leaflet tear at central scallop was identified in 10 cases and 19 patients had either commissural with posterior leaflet or commissural MR.

These findings align with prior research and underscore the importance of 3D imaging in identifying MR mechanisms. Understanding these mechanisms can guide post-procedural monitoring and long-term management. Leaflet tears and subvalvular disruption may predict adverse outcomes and prompt consideration for early surgical intervention.

The second phase of this study will assess the long-term impact of MR severity and mechanism on clinical outcomes.

CONCLUSION

Mitral regurgitation is a frequent and clinically significant complication following PMBC for rheumatic mitral stenosis. 3D TTE is an effective tool for identifying the structural mechanisms responsible. Further longitudinal follow-up is needed to determine the prognostic implications and guide therapeutic strategies.

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