CARDIOLOGIE TUNISIENNE

ARTICLE ORIGINAL

Early Right-Heart Reverse Remodeling Following Transcatheter Edge-to-Edge Mitral Repair

Remodelage inverse précoce du cœur droit après réparation mitrale percutanée bord à bord

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Summary

Introduction : Severe mitral regurgitation (MR) contributes to right-sided cardiac remodeling, pulmonary hypertension, and right ventricular (RV) dysfunction. Transcatheter edge-to-edge repair (MTEER) effectively reduces MR severity, but its impact on RV performance, pulmonary pressures, and tricuspid regurgitation (TR) in real-world practice remains incompletely characterized.

Methods: We conducted a retrospective observational study including 13 consecutive patients with severe MR who underwent MTEER at the Military Hospital of Tunis between January 2022 and June 2025. Comprehensive transthoracic echocardiography was performed before the procedure and at 6-month follow-up. RV systolic function (TAPSE, S′, RVFAC), pulmonary artery systolic pressure (PASP), RV–pulmonary artery (RV–PA) coupling (TAPSE/PASP), TR severity, and MR grade were evaluated according to ASE/EACVI and ESC recommendations. Clinical events at 6 months were recorded.

Results: All patients had severe MR at baseline, with reduced LVEF (35 ± 14%) and significant comorbidity burden. MTEER achieved MR ≤1+ in all patients at 6 months. RV dysfunction was present in 53% at baseline and decreased to 30% post-procedure. Pulmonary hypertension (PASP ≥45 mmHg) declined from 62% to 15%. Mean TAPSE/PASP improved from 0.29 to 0.47, indicating enhanced RV–PA coupling. TR severity also improved: severe TR decreased from 38% at baseline to 0% at follow-up, with most patients exhibiting trivial or mild TR post- procedure. At 6 months, no deaths occurred, and only one patient required rehospitalization for heart failure.

Conclusions: In this small real-world cohort, MTEER was associated with marked reduction of MR severity and favorable right-heart remodeling, including improvements in RV systolic function, pulmonary pressures, RV–PA coupling, and TR grade. These findings reinforce the physiologic benefits of transcatheter MR correction on the right heart and support early consideration of MTEER before irreversible right-sided dysfunction develops. Larger studies are needed to confirm these observations and define their prognostic significance.

Keywords

MitraClip; transcatheter edge-to-edge repair; mitral regurgitation; right ventricular function; RV– pulmonary artery coupling; pulmonary hypertension; tricuspid regurgitation; echocardiography; cardiac remodeling.

Résumé

Introduction :L'insuffisance mitrale (IM) sévère favorise le remodelage des cavités droites, l'hypertension pulmonaire et la dysfonction du ventricule droit (VD). La réparation mitrale percutanée par technique edge-to-edge (MTEER) permet une réduction efficace de l'IM, mais son impact sur la fonction VD, les pressions pulmonaires et la régurgitation tricuspide (RT) en pratique réelle reste imparfaitement caractérisé.

Méthodes : Nous avons mené une étude observationnelle rétrospective incluant 13 patients consécutifs présentant une IM sévère traitée par MTEER à l'Hôpital Militaire de Tunis entre janvier 2022 et juin 2025. Une échocardiographie transthoracique complète a été réalisée avant l'intervention et à 6 mois. La fonction systolique du VD (TAPSE, S′, RVFAC), la pression artérielle pulmonaire systolique (PAPS), le couplage VD–artère pulmonaire (TAPSE/PAPS), la sévérité de la RT et le grade de l'IM ont été évalués selon les recommandations ASE/EACVI et ESC. Les événements cliniques à 6 mois ont été recueillis.

Résultats : Tous les patients présentaient une IM sévère initiale, une fraction d'éjection ventriculaire gauche réduite (35 ± 14 %) et de nombreuses comorbidités. À 6 mois, une IM ≤1+ a été obtenue chez tous les patients. La dysfonction du VD est passée de 53 % à 30 %. La prévalence de l'hypertension pulmonaire (PAPS ≥45 mmHg) a diminué de 62 % à 15 %. Le rapport TAPSE/PAPS s'est amélioré de 0,29 à 0,47, traduisant un meilleur couplage VD–artère pulmonaire. La RT s'est significativement améliorée, avec disparition des formes sévères (38 % à 0 %) et prédominance des formes minimes ou légères au suivi. Aucun décès n'a été observé et une seule réhospitalisation pour insuffisance cardiaque a été rapportée.

Conclusion : Dans cette cohorte en conditions réelles, la MTEER est associée à une réduction marquée de l'IM et à un remodelage favorable du cœur droit. Ces résultats soutiennent une prise en charge précoce avant l'installation d'une dysfonction droite irréversible. Des études de plus grande envergure sont nécessaires pour confirmer ces observations et préciser leur valeur pronostique.

Mots-clés

MitraClip ; réparation bord-à-bord par voie percutanée ; insuffisance mitrale ; fonction ventriculaire droite ; couplage ventricule droit-artère pulmonaire hypertension pulmonaire ; insuffisance tricuspide; échocardiographie ; remodelage cardiaque.

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INTRODUCTION

Severe mitral regurgitation (MR) is a major cause of morbidity and mortality, frequently leading to progressive remodeling of the right heart chambers and the development of pulmonary hypertension (1). Chronic elevation of left atrial pressure due to MR results in backward transmission into the pulmonary circulation, thereby increasing right ventricular (RV) afterload and impairing RV–pulmonary artery coupling. As the disease advances, these hemodynamic changes contribute to RV dysfunction and secondary tricuspid regurgitation (TR), both of which are strong predictors of adverse clinical outcomes, including heart failure hospitalization and mortality (2).

Transcatheter edge-to-edge mitral repair (MTEER) has become an established therapeutic option for patients with severe MR who are not eligible for surgery (3). Beyond reducing MR severity, growing evidence suggests that MTEER may improve right-sided cardiac function by decreasing pulmonary pressures and alleviating RV workload (4). Several studies have reported early and mid-term improvements in RV systolic parameters—such as tricuspid annular plane systolic excursion (TAPSE), tissue Doppler S velocity, and right ventricular fractional area change (RVFAC)—as well as reductions in pulmonary artery systolic pressure (PASP) estimated from tricuspid regurgitation velocity. Right ventricle–to–pulmonary artery (RV–PA) coupling, commonly assessed noninvasively by the ratio of tricuspid annular plane systolic excursion to pulmonary artery systolic pressure (TAPSE/PASP), serves as a surrogate of the RV length–force relationship and carries important prognostic value in heart failure populations (5). Emerging evidence suggests that MTEER can improve RV–PA coupling, highlighting the importance of assessing TAPSE/PASP before and after the procedure to evaluate right ventricular functional recovery and predict clinical outcomes. Changes in TR severity have also been documented, reflecting the dynamic relationship between MR severity, RV function, and right-sided valve competence (6).

Because the available evidence remains limited and heterogeneous, particularly in everyday clinical practice, we present here a descriptive report of our small cohort. The aim is to document observed changes in RV performance, pulmonary pressures, and tricuspid regurgitation after MTEER, providing illustrative insights rather than establishing firm outcomes

METHODS

Study design and population

This retrospective observational study included 13 consecutive patients with severe mitral regurgitation who underwent transcatheter edge-to-edge repair using the MitraClip © system in the Cardiology Department of the Military Hospital of Tunis between January 2022 and June 2025. Patients were eligible if complete echocardiographic data were available both before the procedure and at 6-month follow-up. Those with incomplete imaging or unsuccessful clip implantation were excluded.

Mitral regurgitation assessment

MR severity was graded according to the 2025 ESC echocardiography recommendations (7), integrating qualitative, semi-quantitative, and quantitative parameters. The PISA method served as the reference technique for quantification (EROA, regurgitant volume). MR was classified on a 4-grade scale. Follow-up assessment was performed at 6 months.

Right ventricular systolic function

RV systolic performance was assessed using:

- Tricuspid annular plane systolic excursion (TAPSE)
- Tissue Doppler S wave
- RV fractional area change (RVFAC)

RV dysfunction was defined as TAPSE < 17 mm, S < 9.5 cm/s, or RVFAC < 35(8) Pulmonary hypertension and TR evaluation

Pulmonary artery systolic pressure (PASP) was calculated from TR velocity using the modified Bernoulli equation:

$PASP = 4 \times (TR\ velocity)^2 + estimated\ RAP.$

RAP was inferred from IVC diameter and collapsibility. Tricuspid regurgitation (TR) severity was graded using a multiparametric ASE-recommended approach.

RV–PA coupling was assessed by calculating the ratio of TAPSE to PASP (TAPSE/PASP).

- TAPSE = Tricuspid Annular Plane Systolic Excursion
- PASP = Pulmonary Artery Systolic Pressure

Procedural characteristics

All MitraClip procedures were performed under general anesthesia with continuous TEE and fluoroscopy guidance. The number and type of clips were recorded. Procedural success was defined as residual MR ≤ 2+.

Follow-up

At 6 months, patients underwent clinical and echocardiographic reassessment, including MR grade, RV function, TR severity, and PASP.

STUDY ENDPOINTS

Primary endpoints

- Changes in RV systolic function (TAPSE, S , RVFAC) and in the RV–PA coupling index (TAPSE/PASP)
- Change in pulmonary hypertension
- Change in TR grade

Secondary endpoints:

- All-cause mortality at 6 months
- Heart-failure rehospitalization at 6 months

STATISTICAL ANALYSIS

Given the small sample size, continuous variables were expressed as median (IQR) and compared using Wilcoxon signed-rank tests. Categorical variables were compared using McNemar's test. A p-value < 0.05 was considered statistically significant. Analyses were performed using SPSS Statistics 22.

RESULTS

The study included 13 patients with a mean age of 65 ± 8 years (range: 52–78), of whom 11 (78%) were men. Baseline characteristics of the cohort including comorbidities are depicted in Table 1.

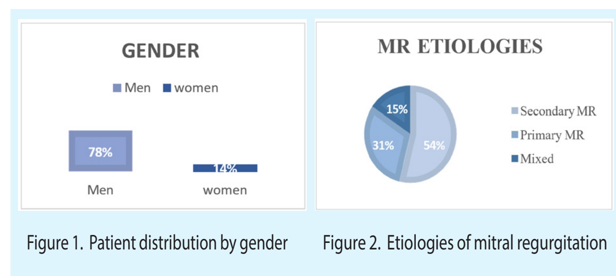

Figure 1. Patient distribution by gender

Figure 2. Etiologies of mitral regurgitation

The majority of patients had severe mitral regurgitation (MR grade 4) and were symptomatic, with 12/13 (93%) in New York Heart Association (NYHA) functional class III–IV. Baseline left ventricular systolic function was reduced, with a mean LVEF of 35 ± 14%, LV dysfunction was predominantly caused by ischemic cardiomyopathy. The majority of patients had secondary mitral regurgitation (9 patients).

Patients with reduced LV function received a sufficient pharmacological heart failure treatment consisting of ACE inhibitor or AT blocker or ARNI (87.3%), beta-blocker (87.3%), mineralocorticoid receptor antagonists (45.5%) and diuretics (92.7%).

Table 1. Baseline Characteristics of the Study Population (n = 13)

Variable	Value
Total number of patients	13
Age (years)	65 ± 8 (mean ± SD)
Sex, n	Male 11 – Female 2
NYHA functional class III–IV	12
Euro SCORE II (%)	Range: 5.91–21.69%
STS score (%)	Repair: 4.24–22.8% Replacement: 8.55–31.9%
Coronary artery disease, n	Yes 6 – No 7
Atrial fibrillation, n	3
Pacemaker / ICD implanted, n	2
History of congestive heart failure, n	12
Previous percutaneous coronary angioplasty, n	6
History of CABG, n	0
Mitral regurgitation etiology, n	Secondary MR: 9 Primary MR: 4
Mean Left ventricular ejection fraction (%)	35 ± 14
MR severity (pre-MitraClip)	Grade 4
ACE/ARB/ARNI, n	9
Beta-blocker, n	12
Mineralocorticoid receptor antagonists, n	8
SGLT2 inhibitors, n	12
Diuretics, n	13

Based on anatomical evaluation, MitraClip implantation was considered ideal in 8 patients and feasible but complex in 5 . According to current guidelines, an ideal anatomical profile predicts a higher likelihood of procedural success and lower risk of complications, whereas a feasible but complex anatomy may still allow repair but requires careful procedural planning and operator expertise. Overall, all patients in the cohort met criteria for MitraClip eligibility, consistent with guideline recommendations for edge-to-edge repair.

MitraClip implantation was performed using a single clip in 8 patients and two clips in 5 patients . The

number of clips was determined based on the mitral regurgitation severity, anatomical feasibility, and intra-procedural echocardiographic guidance to achieve optimal reduction of MR.

TEE and TTE control at 06 months Following the MTEER, showed that MR improved in all patients. Pre-procedure, all patients had severe MR. Post-procedure, three patients improved to trivial MR, 10 patients improved to mild MR; no patient remained in the severe or moderate category, and no worsening was observed. Quantitative assessment confirmed these improvements as showed in Table 3. These findings collectively indicate a substantial reduction in MR severity following MitraClip repair in this cohort. No significant difference in the reduction of the MR between patients with secondary or primary MR was detectable.

Table 2. Mitral Regurgitation (MR) Severity and Quantitative Parameters Before and After TEER

Parameter	Pre-procedure	Post-procedure	Change / Comment
MR Grade	All patients: Severe (n = 13)	Trivial: 3 Mild: 10 Moderate/ Severe: 0	Significant reduction; no worsening observed
Systolic Orifice Area (SOR)	0.45 ± 0.15 cm²	14.0 ± 3.0 mm² (range 10–25 mm²)	Marked decrease in regurgitant orifice
Regurgitant Volume (VR)	55 ± 22 mL	17 ± 8 mL (range 8–37 mL)	Consistent improvement
Pulmonary Vein Flow Pattern	Predominantly diastolic-dominant (S < D)	Systolic-dominant (S > D): 10 Diastolic-dominant (S < D): 3	Abolition of systolic flow reversal

Before Mitra Clip implantation, right ventricular (RV) dysfunction was present in 7/13 patients according to at least one of the following parameters: TAPSE <17 mm, S   <9.5 cm/s, or RVFAC <35%. Individually, RV dysfunction was observed in 7 patients (53%) based on TAPSE, 5 patients based on S', and 5 patients based on RVFAC. Pulmonary hypertension, defined as systolic pulmonary artery pressure ≥45 mmHg, was present in 8/13 patients.

After MitraClip implantation, right ventricular (RV) function improved in most patients. RV dysfunction was present in 4 out of 13 patients (30%). Pulmonary hypertension, defined as systolic pulmonary artery pressure ≥45 mmHg, persisted in 2 patients.

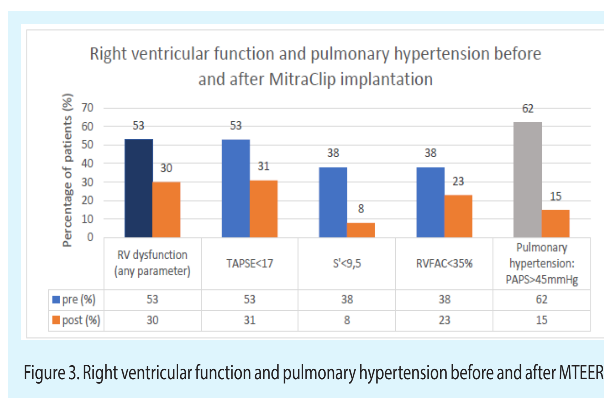

Figure 3. Right ventricular function and pulmonary hypertension before and after MTEER

In our cohort, RV–PA coupling assessed by TAPSE/PASP improved significantly after MitraClip. Mean TAPSE/PASP increased from 0.29 ± SD pre-procedure to 0.47 ± SD post-procedure (Δ = +0.18). This improvement was primarily mediated by a reduction in PASP, while TAPSE showed modest interval changes..

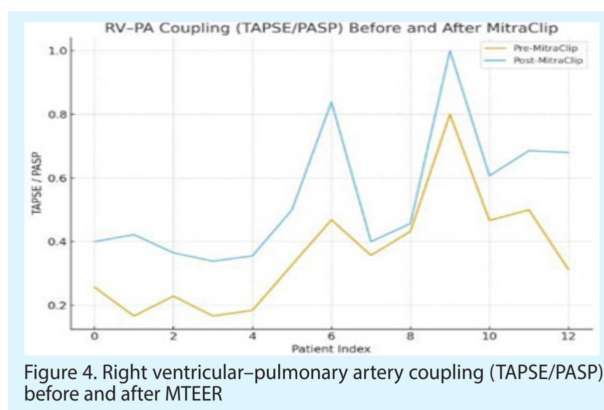

Figure 4. Right ventricular–pulmonary artery coupling (TAPSE/PASP) before and after MTEER

After MitraClip implantation, a marked improvement in tricuspid regurgitation (TR) severity was observed. Before the procedure, 5 patients had severe TR, 2 mild TR, 5 patients moderate TR and one patient severe TR. After procedure, 6 patients had trivial TR, 6 patients mild TR, and only 1 patient remained with moderate TR. No cases of severe TR persisted after the intervention.

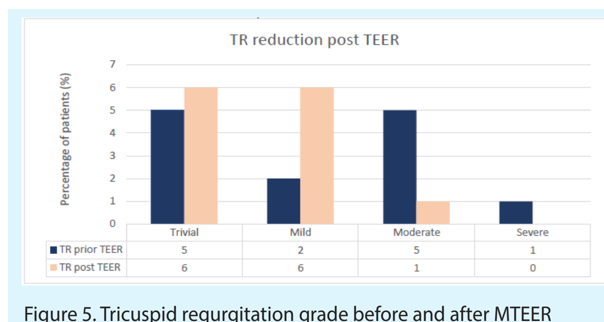

Figure 5. Tricuspid regurgitation grade before and after MTEER

During the observational period a total of 4 hospitalizations had occurred. However, only 1 of them was due to cardiac decompensation. The rest of the events were due to non-cardiovascular causes. No patients experienced all-cause mortality.

Table 3. Clinical Outcomes at 6 Months follow up

Outcome	n	%
All-cause mortality	0	0
Rehospitalization for heart failure	1	7.7
Rehospitalization for other causes	3	23.1
Total rehospitalizations (all causes)	4	30.8
Composite endpoint (death + HF rehospitalization)	1	7.7

DISCUSSION

observed that MR reduction was accompanied by measurable improvements in right-heart parameters at 6-month follow-up. The main findings were:

- An overall trend toward improved RV systolic function, as assessed by TAPSE, S velocity, and RVFAC.
- A decrease in pulmonary artery systolic pressure (PASP)
- Stabilization or reduction in TR severity in a subset of patients, suggesting partial reversal of functional TR.
- Significant improvement in RV–PA coupling, as assessed by the TAPSE/PASP ratio, following MitraClip implantation.

COMPARISON WITH PREVIOUS STUDIES

Impact on RV systolic function

Our results align with several published studies showing that MTEER is associated with improvements in RV performance.

Vitarrelli et al. demonstrated an early increase in TAPSE and RVFAC as soon as 30 days after implantation, particularly in patients with baseline RV dysfunction (9). The change in RV function can be explained by reduced RV afterload after MTEER. Previous research suggested that reverse remodeling occurs more frequently in patients with secondary MR (10). In contrast, our findings showed no major difference between the two subgroups (3)). Overall, patients with secondary MR generally have more comorbidities and more advanced cardiac disease. This is supported by our analysis, which indicates that patients with higher STS risk scores are less likely to undergo reverse RV remodeling, and that those with severe LV dysfunction exhibit smaller improvements in RV performance. In line with these findings, our cohort showed a consistent direction of improvement, reinforcing the hypothesis that relieving left-sided volume overload reduces RV strain, allowing for functional recovery.

Impact on pulmonary hypertension and RV-PA coupling

Our results demonstrating significant PASP reduction and improved RV–PA coupling after MTEER are consistent with recent reports. Koschutnik et al., Adamo et al., and

Solsona-Caravaca et al (11–13). all observed decreases in PASP and increases in TAPSE/PASP following TEER, highlighting favorable right-heart remodeling. The magnitude of changes in our cohort aligns with these findings, supporting the reproducibility of the hemodynamic benefits of MR correction. These data reinforce the value of assessing PASP and TAPSE/PASP during post- procedural follow-up to monitor RV functional recovery, with a TAPSE/PASP ratio ranging between 0.3-0.4 mm / mm Hg being associated with RV-PA uncoupling and increased mortality risk (8).

Impact on tricuspid regurgitation:

Our findings of tricuspid regurgitation (TR) improvement following M-TEER implantation are consistent with recent reports in the literature. Jagadeesan et al. (14) demonstrated that significant mitral regurgitation reduction is frequently accompanied by concomitant TR reduction, highlighting the interplay between left- and right-heart valve function. Similarly, Matsumoto et al. (15) reported that patients undergoing M-TEER often experience regression of functional TR, and identified factors predicting TR improvement, such as baseline TR severity and right ventricular function. In our cohort, we observed comparable trends, with a subset of patients showing stabilization or reduction of TR severity post-procedure. These data support the concept that correcting mitral regurgitation can induce favorable remodeling of the tricuspid valve apparatus and right heart, emphasizing the importance of evaluating TR before and after M-TEER to assess the full hemodynamic benefit of the intervention.

CLINICAL IMPLICATIONS

These findings highlight the importance of evaluating RV function and pulmonary pressures when considering M-TEER therapy. Patients with advanced RV dysfunction or longstanding pulmonary hypertension may still

benefit from MR reduction, but their potential for reverse remodeling may be limited. The observed improvements in RV parameters and PASP suggest that MR correction may positively influence right-heart physiology, potentially contributing to better functional status and fewer heart failure exacerbations. This underscores the importance of timely referral for transcatheter MR repair before irreversible right-heart damage develops.

PROGNOSTIC IMPLICATIONS

Previous research has consistently shown that baseline RV dysfunction and pulmonary hypertension are associated with increased mortality and higher rehospitalization rates after M- TEER. In a multicenter analysis, Doldi et al. found that RV dysfunction was an independent predictor of 2-year mortality after M-TEER, with a significantly higher risk in patients with impaired RV performance (16). Guzman et al. reported that pulmonary hypertension was common and correlated with increased mortality and heart-failure readmissions following transcatheter mitral repair. Similar registries have shown that failure to reduce PASP after M- TEER or very high baseline PASP identifies a subgroup with less favorable remodeling and worse event rates (17). The trends observed in our cohort are aligned with this evidence, indicating that improvements in RV function and pulmonary pressures may translate into better clinical outcomes.

Although our study was not powered to analyze survival or rehospitalization patterns, the observed changes support the concept that right-heart response to MR reduction can serve as a meaningful prognostic marker.

STUDY LIMITATIONS

The major limits of the present study are related to its observational nature, relatively small sample size and lack of a reference standard for RV functional evaluation (such as magnetic resonance imaging or three-dimensional echocardiography). Moreover, it reflects the initial experience of our center and thus the results must be regarded as hypothesis generating and exploratory and require validation in further larger studies.

CONCLUSIONS

Despite these limitations, our findings contribute to the growing body of evidence supporting the beneficial effects of M-TEER on right-heart function and pulmonary pressures. MR reduction appears to promote partial reverse remodeling of the RV and improvement in pulmonary hypertension at mid-term follow-up. Further studies with larger cohorts and longer follow-up are needed to better define the trajectory and prognostic impact of right-heart changes after transcatheter mitral repair.

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