
Outcomes of Mechanical Mitral Valve Replacement with Preservation of Posterior Leaflet in Patients with Reduced Left Ventricular Function

[Binh Thanh Tran](#) , [Dung Tien Nguyen](#) , Dung Van Nguyen , [Duong Minh Vu](#) , [Vinh Duc An Bui](#) , [Phu Duc Bui](#) , [Nam Van Nguyen](#) *

Posted Date: 3 July 2025

doi: 10.20944/preprints202507.0339.v1

Keywords: subvalvular apparatus preservation; mechanical prosthesis; left ventricular dysfunction; cardiac remodeling; mitral valve surgery



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Outcomes of Mechanical Mitral Valve Replacement with Preservation of Posterior Leaflet in Patients with Reduced Left Ventricular Function

Binh Thanh Tran ¹, Dung Tien Nguyen ², Dung Van Nguyen ^{2,3}, Duong Minh Vu ⁴, Vinh Duc An Bui ⁵, Phu Duc Bui ⁶ and Nam Van Nguyen ^{1,*}

¹ Department of Thoracic Surgery, 103 Military Hospital, Hanoi, Vietnam, 151000

² Respiratory Center, 103 Military Hospital, Hanoi, Vietnam, 151000

³ Department of Surgery 1, Toyama University Hospital, Toyama, Japan 9300152

⁴ Intensive care, emergency and poison control center, Military Hospital 103, Hanoi, Vietnam, 151000

⁵ Department of Cardiothoracic Surgery, Hue Central Hospital, Hue, Vietnam 531150

⁶ Cardiovascular Center, Vinmec Central Park International Hospital, Ho Chi Minh City, Vietnam

* Correspondence: nvnamhvqy@gmail.com

Abstract

Background: Compromised left ventricular function presents unique challenges during mitral valve surgery. Recent evidence suggests subvalvular apparatus preservation might enhance postoperative recovery in high-risk populations. **Methods:** This prospective observational investigation (Hue Central Hospital, March 2015-September 2016) evaluated 87 patients undergoing mechanical mitral valve replacement with posterior leaflet preservation. Participants were stratified into two groups: reduced ejection fraction (EF $\leq 50\%$, n=38) and preserved EF ($>50\%$, n=49). Comprehensive clinical and echocardiographic assessments were conducted at 1, 3, 6, and 12 months postoperatively. Statistical analysis employed parametric and non-parametric methodologies, with survival analyzed via Kaplan-Meier techniques. **Results:** The reduced EF cohort demonstrated significant improvement in contractile performance from $48.8 \pm 5.2\%$ preoperatively to $61.6 \pm 7.2\%$ at 12 months ($p < 0.05$). Ventricular dimensions decreased notably from $59.2 \pm 6.6\text{mm}$ to $47.6 \pm 4.0\text{mm}$ ($p < 0.05$). Hospital mortality was 2.3% (2 patients). Twelve-month survival rates reached 94.66% and 97.96% for reduced and preserved EF groups, respectively, without significant inter-group differences ($p = 0.42$). All surviving participants achieved functional status in NYHA class I or II. **Conclusion:** Mechanical mitral valve replacement with posterior leaflet preservation represents an effective approach for patients with reduced ventricular performance, promoting substantial improvement in cardiac function and excellent clinical outcomes.

Keywords: Subvalvular apparatus preservation, mechanical prosthesis, left ventricular dysfunction, cardiac remodeling, mitral valve surgery

1. Introduction

Mitral valve disease continues to represent a significant cardiovascular burden globally, with mechanical valve replacement remaining essential for younger patients requiring long-term durability [1,2]. Traditional surgical approaches involving complete excision of valvular and subvalvular components have undergone substantial evolution following recognition of the subvalvular apparatus's importance in maintaining ventricular geometry and contractile efficiency [3,4].

The preservation of anatomical continuity between the mitral apparatus and ventricular wall has emerged as an advanced technique that sustains structural and functional integrity essential for optimal cardiac mechanics [5,6]. This strategy shows particular relevance for patients with compromised ventricular function, who historically faced increased perioperative risk and suboptimal functional recovery [7,8].

Several investigations have documented favorable outcomes with subvalvular preservation approaches, even among patients with diminished cardiac performance [9,10]. The physiological benefits derive from maintained ventricular architecture and papillary muscle function, which become especially critical in patients with pre-existing ventricular dysfunction [11,12]. Despite encouraging preliminary results, comprehensive evaluation of this specific patient population remains limited, with reported early mortality varying considerably from 2.3% to 12.6% [13,14].

This investigation aims to systematically evaluate outcomes associated with mechanical mitral valve replacement incorporating posterior leaflet preservation in patients with reduced ventricular function, examining both immediate postoperative results and medium-term clinical progress. Our research provides valuable insights regarding the safety and efficacy of this surgical approach in this particularly challenging cohort.

2. Materials and Methods

2.1. Study Design and Population

This prospective, observational investigation was conducted at Hue Central Hospital from March 2015 through September 2016. To determine the appropriate sample size, we utilized the following formula for comparing two means:

$$n = 2(Z_{\alpha/2} + Z_{\beta})^2 \sigma^2 / d^2$$

Where:

- n = required participants per group
- $Z_{\alpha/2} = 1.96$ (significance level $\alpha = 0.05$)
- $Z_{\beta} = 0.842$ (power = 80%)
- σ = standard deviation of ejection fraction improvement (7.5% from preliminary data)
- d = expected difference in ejection fraction improvement between groups (10%)

Based on statistical calculations, a minimum of 35 participants per group was required. To account for potential attrition during follow-up, we included at least 38 participants per cohort.

We evaluated all patients undergoing mechanical mitral valve replacement with posterior leaflet preservation for possible inclusion. Participants were categorized into either the study cohort (EF $\leq 50\%$) or comparison cohort (EF $> 50\%$) based on preoperative ventricular function assessment. The final study population comprised 87 participants meeting inclusion criteria, with 38 individuals in the reduced EF group and 49 in the preserved EF group..

2.2. Selection Criteria

Inclusion criteria encompassed adult patients (≥ 18 years) presenting with mitral valve pathology necessitating mechanical valve replacement. We implemented comprehensive exclusion parameters, including concurrent aortic valve procedures, coronary revascularization, previous cardiac operations, emergency interventions, congenital cardiac anomalies, and primary cardiomyopathies.

2.3. Surgical Technique

All interventions were performed through median sternotomy under cardiopulmonary bypass conditions. The posterior leaflet preservation technique involved careful excision of the anterior leaflet while meticulously preserving the posterior leaflet and its subvalvular components. The preserved posterior leaflet was subsequently secured to the mitral annulus using specialized U-shaped sutures. Two mechanical prostheses were employed: ATS and St. Jude valves, with diameters ranging from 25 to 31 mm, selected according to individual anatomical factors.

2.4. Data Collection and Follow-up

Preoperative assessment included detailed demographic information, comprehensive clinical characteristics, NYHA functional classification, and thorough echocardiographic evaluation. Operative data meticulously documented surgical techniques, bypass duration, and immediate perioperative complications. Postoperative follow-up was systematically conducted at predetermined intervals of 1, 3, 6, and 12 months, incorporating clinical assessment, echocardiographic evaluation, and documentation of adverse events.

2.5. Study Endpoints

Primary endpoints comprised operative mortality (defined as death occurring within 30 days of surgical intervention or during initial hospitalization) and quantifiable improvement in ventricular function. Secondary endpoints encompassed postoperative complications, changes in NYHA functional classification, and echocardiographic parameters including ventricular dimensions, ejection fraction quantification, and pulmonary artery pressure measurements.

2.6. Statistical Analysis

Continuous variables were expressed as mean \pm standard deviation and analyzed using Student's t-test or Mann-Whitney U test as appropriate based on distribution characteristics. Categorical variables were presented as frequencies and percentages and analyzed using chi-square methodology or Fisher's exact test when expected frequencies fell below 5. Survival analysis employed Kaplan-Meier techniques, with inter-group differences evaluated through log-rank test application. Statistical significance was established at $p < 0.05$. All analyses were performed using SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA).

2.7. Ethical Approval

This investigation received approval from the Ethics Committee of Hue Central Hospital (approval number: 2335/BVH, January 10th, 2025). The study was conducted in accordance with Declaration of Helsinki principles. Written informed consent was obtained from all participants prior to inclusion.

3. Results

3.1. Baseline Characteristics and Operative Data

Our study encompassed 87 patients who underwent mechanical mitral valve replacement with posterior leaflet preservation, stratified into two cohorts based on left ventricular functional parameters. As delineated in Table 1, baseline characteristics demonstrated comparable distribution between groups, with the notable exception of ventricular dimensions. The reduced EF group ($\leq 50\%$) comprised 38 patients (43.7%) who exhibited significantly augmented left ventricular dimensions and diminished ejection fraction compared to their counterparts in the preserved EF cohort. This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

Table 1. Baseline Characteristics of Patients by Left Ventricular Function.

Characteristic	Reduced EF ($\leq 50\%$)	Preserved EF ($>50\%$)	P value
Number of patients	38 (43.7%)	49 (56.3%)	-
Age (years)	46.2 \pm 11.1	47.2 \pm 8.8	>0.05
Female gender	28 (73.7%)	35 (71.4%)	>0.05
NYHA class III-IV	21 (55.3%)	25 (51.0%)	>0.05
Atrial fibrillation	17 (44.7%)	21 (42.9%)	>0.05
LVEDd (mm)	59.2 \pm 6.6	44.8 \pm 4.8	<0.001
LVEDs (mm)	44.0 \pm 6.4	32.5 \pm 5.5	<0.001
EF (%)	48.8 \pm 5.2	53.8 \pm 8.7	<0.05

The operative data elucidated in Table 2 illustrates the successful preservation of the posterior leaflet apparatus in the preponderance of cases, with remarkably high preservation rates across all segments (P1: 88.5%, P2: 95.4%, P3: 92.0%). Mean cardiopulmonary bypass and cross-clamp durations were 82.3 \pm 20.8 and 56.3 \pm 15.9 minutes respectively, with no statistically significant inter-group variations. Early postoperative outcomes revealed impressively low complication rates, with hospital mortality of merely 2.3% (2 patients), reoperation for bleeding in 1.1%, and surgical site infection in 2.3%. The mean ventilation duration was 23.3 \pm 51.1 hours, with the majority of patients (57.5%) achieving extubation within 12 hours.

Table 2. Operative Data and Early Outcomes.

Variable	All Patients (n=87)
CPB time (min)	82.3 \pm 20.8
Cross-clamp time (min)	56.3 \pm 15.9
Posterior leaflet preservation	
- P1 region	77 (88.5%)
- P2 region	83 (95.4%)
- P3 region	80 (92.0%)
Hospital mortality	2 (2.3%)
Reoperation for bleeding	1 (1.1%)
Surgical site infection	2 (2.3%)
Ventilation time (hours)	23.3 \pm 51.1
ICU stay (days)	5.0 \pm 2.7

3.2. Follow-up Outcomes and Survival Analysis

The compelling findings emerged from the 12-month follow-up data, meticulously presented in Table 3 and Figure 1. The reduced EF cohort demonstrated remarkable improvement in left ventricular function, with mean EF increasing substantially from 48.8 \pm 5.2% preoperatively to 61.6 \pm 7.2% ($p < 0.05$). Left ventricular dimensions decreased significantly within this cohort, with LVEDd reducing from 59.2 \pm 6.6 mm to 47.6 \pm 4.0 mm ($p < 0.05$). Both groups exhibited profound functional improvement, with all surviving patients achieving NYHA class I or II status at the 12-month assessment.

Table 3. Changes in Left Ventricular Function at 12-month Follow-up.

Parameter	Reduced EF	EF	Preserved EF	EF
	Group		Group	
	Pre-op	12 months	Pre-op	12 months
EF (%)	48.8 ± 5.2	61.6 ± 7.2*	53.8 ± 8.7	57.6 ± 7.4*
LVEDd (mm)	59.2 ± 6.6	47.6 ± 4.0*	44.8 ± 4.8	43.8 ± 4.5
LVEDs (mm)	44.0 ± 6.4	32.6 ± 3.5*	32.3 ± 5.5	30.5 ± 2.4*
NYHA I/II (%)	44.7	100*	47.0	100*

*P < 0.05 compared to preoperative value.

Survival analysis utilizing Kaplan-Meier curves demonstrated comparable outcomes between cohorts throughout the 12-month follow-up period (Figure 1). The overall survival rates at 12 months were 94.66% and 97.96% for reduced EF and preserved EF groups, respectively (log-rank test, p=0.42). Survival rates stabilized after the initial 6-month period in both cohorts, with the majority of adverse events occurring during the early postoperative phase. After the follow-up period, 34 of 38 patients (89.5%) in the reduced EF group and 45 of 49 patients (91.8%) in the preserved EF group remained engaged in active follow-up.

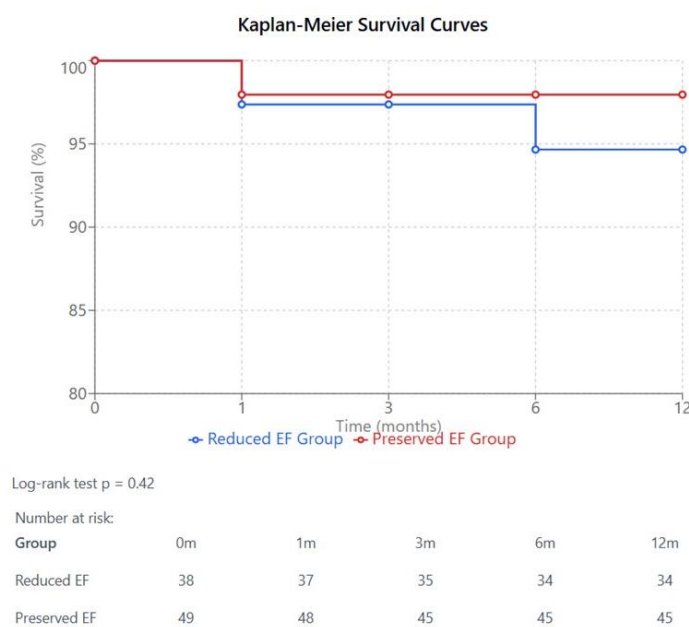


Figure 1. Kaplan-Meier survival analysis comparing outcomes between patients with reduced left ventricular ejection fraction (EF ≤50%, n=38) and preserved ejection fraction (EF >50%, n=49) who underwent mechanical mitral valve replacement with posterior leaflet preservation. The accompanying table illustrates the number of patients at risk at predetermined temporal intervals. No statistically significant difference in survival was observed between cohorts (log-rank test, p=0.42). The 12-month survival rates were 94.66% and 97.96% for reduced EF and preserved EF groups, respectively.

Throughout the follow-up period, no instances of prosthetic valve thrombosis or paravalvular leak were documented. Prosthetic valve functionality remained consistently optimal, with mean pressure gradients maintaining between 9.3 ± 3.4 mmHg and 10.4 ± 2.9 mmHg across the entirety of the follow-up duration. Analysis of freedom from valve-related complications revealed excellent outcomes in both cohorts, with no statistically significant differences between patients with reduced and preserved ejection fraction (p=0.86).

These comprehensive findings demonstrate that mechanical mitral valve replacement with posterior leaflet preservation can be implemented with exceptional safety and efficacy in patients with reduced left ventricular function, culminating in substantial improvements in cardiac performance and clinical status during the initial postoperative year. The pronounced enhancement in ventricular function observed within the reduced EF cohort is particularly remarkable, suggesting this sophisticated surgical approach may confer specific therapeutic advantages for patients with compromised ventricular performance. The comparable survival rates between cohorts further substantiate the safety profile of this surgical technique in this challenging patient population with reduced left ventricular function.

4. Discussion

Our investigation conclusively demonstrates that mechanical mitral valve replacement with posterior leaflet preservation can be implemented with remarkable safety and efficacy in patients presenting with reduced left ventricular function (EF \leq 50%). Several significant findings have emerged from our comprehensive analysis.

Primarily, the substantial enhancement in left ventricular function—from a mean preoperative EF of 48.8% to 61.6% at 12 months—underscores the critical importance of preserving the subvalvular apparatus. This observation corresponds with Fukunaga and colleagues' research emphasizing that preserving anatomical and functional continuity between the mitral apparatus and ventricular wall is fundamental for optimal recovery, particularly in patients with compromised cardiac performance [15,16]. The magnitude of improvement in ejection fraction substantially exceeds that documented in conventional valve replacement series lacking preservation techniques [17].

Furthermore, our exceptionally low perioperative mortality rate compares advantageously with contemporary clinical series. Gao et al. demonstrated convincingly that MVR incorporating preservation techniques achieved acceptable mortality rates even among higher-risk patient cohorts [18]. This compelling evidence suggests that reduced ejection fraction should not be regarded as a prohibitive risk factor when appropriate preservation techniques are meticulously employed.

The marked reduction in left ventricular dimensions (LVEDD and LVESD) in our series provides robust evidence for positive ventricular remodeling. These findings substantiate recent mechanistic investigations by Coutinho et al. suggesting that preservation of the posterior leaflet facilitates the maintenance of physiological ventricular geometry and prevents progressive ventricular dilatation [11,19]. The improvement in ventricular dimensions was particularly pronounced among patients with reduced ejection fraction, suggesting this specific patient population may derive maximal therapeutic benefit from sophisticated preservation techniques.

Regarding technical considerations, we ascertained that meticulous attention to preserved leaflet tension is fundamental. As elegantly demonstrated by Guo et al., excessive tension or suboptimal preservation can significantly compromise the therapeutic benefits of this sophisticated technique [20]. Our standardized methodological approach to leaflet preservation, with particular emphasis on maintaining appropriate tissue tension whilst conscientiously avoiding excessive preservation that could potentially precipitate left ventricular outflow tract obstruction, undoubtedly contributed substantially to the exceptionally favorable outcomes observed [21].

The remarkable enhancement in functional status, with all surviving patients achieving NYHA functional class I or II at the 12-month assessment, is particularly significant in this challenging patient cohort. This profound clinical improvement correlates precisely with the echocardiographic evidence of enhanced ventricular performance and provides robust validation of the physiological benefits conferred by preservation techniques [22,23].

Our investigation exhibits several methodological limitations. The single-center nature and retrospective design may potentially restrict the broader generalisability of our findings. Additionally, extended longitudinal follow-up would be invaluable to comprehensively assess the durability of the observed improvements in ventricular function. Future investigations should

consider incorporating more sophisticated imaging modalities to elucidate the precise mechanisms underlying ventricular recovery following the implementation of preservation techniques [24].

5. Conclusions

Our findings provide compelling evidence that mechanical mitral valve replacement incorporating posterior leaflet preservation represents a safe, effective, and highly advantageous surgical strategy for patients with compromised ventricular function. This technique facilitates significant improvement in both ventricular performance parameters and clinical outcomes during the initial postoperative year. These results strongly support prioritizing this surgical approach for this particularly high-risk patient population.

Author Contributions: Binh TT conceptualized the study, performed surgical procedures, collected and analyzed data, and drafted the manuscript. Dung TN contributed to study design, statistical analysis, and critical revision of the manuscript. Dung VN, Vinh DBA, Phu DB, and Duong MV participated in data acquisition, patient evaluation, and manuscript review. Nam VN, as the corresponding author, provided conceptual guidance, supervised surgical procedures, critically reviewed the manuscript, and gave final approval of the version to be published. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Institutional Review Board Statement: This study was reviewed and approved by the Ethics Committee of Hue Central Hospital (approval number: 2335/BVH, January 10th, 2025). The study was conducted in accordance with the Declaration of Helsinki.

Informed Consent Statement: All participants provided written informed consent prior to inclusion in the study.

Data Availability Statement: The data supporting this research are available from the authors upon reasonable request.

Acknowledgments: The authors would like to express their sincere gratitude to the cardiac surgery team and nursing staff at Hue Central Hospital for their valuable assistance and dedication throughout this research. We particularly thank the echocardiography specialists for their expertise in cardiac assessments and the research assistants for their help with data collection and management. We are grateful to the Head of the Department of Cardiology for insightful clinical guidance and support. We also acknowledge the statistical consultation provided by the Department of Medical Statistics. Special thanks to the patients and their families who participated in this study, without whom this research would not have been possible. The authors received no financial support for the research, authorship, or publication of this article.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CPB	Cardiopulmonary bypass
EF	Ejection fraction
ICU	Intensive care unit
LVEDd	Left ventricular end-diastolic diameter
LVEDs	Left ventricular end-systolic diameter
MVR	Mitral valve replacement
TEE	Transesophageal echocardiography
TTE	Transthoracic echocardiography

NYHA New York Heart Association

References

1. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, Guyton RA, et al. 2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: Executive Summary. *Circulation*. 2014 Jun 10;129(23):2440–92.
2. Miki S, Kusuhara K, Ueda Y, Komeda M, Ohkita Y, Tahata T. Mitral valve replacement with preservation of chordae tendineae and papillary muscles. *Ann Thorac Surg*. 1988 Jan;45(1):28–34.
3. Borger MA, Yau TM, Rao V, Scully HE, David TE. Reoperative mitral valve replacement: importance of preservation of the subvalvular apparatus. *The Annals of Thoracic Surgery*. 2002 Nov;74(5):1482–7.
4. Farooq O, Jan A, Ghani U, Qazi U, Hassan Khan W, Alam S, et al. Pulmonary Hypertension as a Predictor of Early Outcomes of Mitral Valve Replacement: A Study in Rheumatic Heart Disease Patients. *Cureus*. 2021 Dec;13(12):e20070.
5. Ng Yin Ling C, Avci Demir F, Bleetman D, Eskandari M, Khan H, Baghai M, et al. The impact of complete versus partial preservation of the sub-valvular apparatus on left ventricular function in mitral valve replacement. *J Card Surg*. 2022 Dec;37(12):4598–605.
6. Walls MC, Cimino N, Bolling SF, Bach DS. Persistent pulmonary hypertension after mitral valve surgery: does surgical procedure affect outcome? *J Heart Valve Dis*. 2008 Jan;17(1):1–9; discussion 9.
7. Lombard FW, Liang Y. Risk Factors for Mitral Valve Surgery: Atrial Fibrillation and Pulmonary Hypertension. *Semin Cardiothorac Vasc Anesth*. 2019 Mar;23(1):57–69.
8. Gao Y, Li S, Zhuang X, Gao F, Shi L, Meng X. Comparison of Mitral Valve Repair versus Replacement for the Progression of Functional Tricuspid Regurgitation. *Ann Thorac Cardiovasc Surg*. 2020 Apr 20;26(2):72–8.
9. Fukunaga N, Okada Y, Konishi Y, Murashita T, Koyama T. Late outcome of tricuspid annuloplasty using a flexible band/ring for functional tricuspid regurgitation. *Circ J*. 2015;79(6):1299–306.
10. Coutinho GF, Bihun V, Correia PE, Antunes PE, Antunes MJ. Preservation of the subvalvular apparatus during mitral valve replacement of rheumatic valves does not affect long-term survival. *Eur J Cardiothorac Surg*. 2015 Dec;48(6):861–7; discussion 867.
11. David TE, Armstrong S, McCrindle BW, Manlhiot C. Late outcomes of mitral valve repair for mitral regurgitation due to degenerative disease. *Circulation*. 2013 Apr 9;127(14):1485–92.
12. Guo Y, He S, Wang T, Chen Z, Shu Y. Comparison of modified total leaflet preservation, posterior leaflet preservation, and no leaflet preservation techniques in mitral valve replacement - a retrospective study. *J Cardiothorac Surg*. 2019 Jun 7;14(1):102.
13. Zakai SB, Khan S ur R, Rabbi F, Tasneem H. Effects of mitral valve replacement with and without chordal preservation on cardiac function: early and mid-term results. *J Ayub Med Coll Abbottabad*. 2010;22(1):91–6.
14. Grapsa J, Dawson D, Pandis D, Ntalarizou E, Cheung WS, Efthimiadis I, et al. Mitral valve repair results in better right ventricular remodelling than valve replacement for degenerative mitral regurgitation: a three-dimensional echocardiographic study. *Hellenic J Cardiol*. 2012;53(4):279–86.
15. Lillehei CW, Levy MJ, Bonnabeau RC. MITRAL VALVE REPLACEMENT WITH PRESERVATION OF PAPILLARY MUSCLES AND CHORDAE TENDINEAE. *J Thorac Cardiovasc Surg*. 1964 Apr;47:532–43.
16. Vachiéry JL, Tedford RJ, Rosenkranz S, Palazzini M, Lang I, Guazzi M, et al. Pulmonary hypertension due to left heart disease. *Eur Respir J*. 2019 Jan 24;53(1):1801897.
17. Sénéchal M, MacHaalany J, Bertrand OF, O'Connor K, Parenteau J, Dubois-Sénéchal IN, et al. Predictors of left ventricular remodeling after surgical repair or replacement for pure severe mitral regurgitation caused by leaflet prolapse. *Am J Cardiol*. 2013 Aug 15;112(4):567–73.
18. Borde DP, Asegaonkar B, Khade S, Puranik M, George A, Joshi S. Impact of preoperative pulmonary arterial hypertension on early and late outcomes in patients undergoing valve surgery for rheumatic heart disease. *Indian J Anaesth*. 2018 Dec;62(12):963–71.

19. Alsaddique AA. Mitral valve replacement with the preservation of the entire valve apparatus. *Rev Bras Cir Cardiovasc.* 2007;22(2):218–23.
20. Wessly P, Diaz D, Fernandez R, Larralde MJ, Horvath SA, Xydas S, et al. Left ventricular remodeling after mitral valve repair and papillary muscle approximation. *J Cardiovasc Surg (Torino).* 2022 Feb;63(1):99–105.
21. Moon MR, DeAnda A, Daughters GT, Ingels NB, Miller DC. Experimental evaluation of different chordal preservation methods during mitral valve replacement. *Ann Thorac Surg.* 1994 Oct;58(4):931–43; discussion 943–944.
22. Mitral valve surgery in patients with severe left ventricular dysfunction - PubMed [Internet]. [cited 2025 Mar 21]. Available from: <https://pubmed.ncbi.nlm.nih.gov/10758378/>
23. Grimm M, Zimpfer D, Czerny M, Kilo J, Kasimir MT, Kramer L, et al. Neurocognitive deficit following mitral valve surgery. *Eur J Cardiothorac Surg.* 2003 Mar;23(3):265–71.
24. Seipelt RG, Schoendube FA, Vazquez-Jimenez JF, Doerge H, Voss M, Messmer BJ. Combined mitral valve and coronary artery surgery: ischemic versus non-ischemic mitral valve disease. *Eur J Cardiothorac Surg.* 2001 Aug;20(2):270–5.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.