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Research Article

Comparative Analysis of Short-Term Outcomes in Thoracoscopic Minimally Invasive Versus Traditional Mitral Valve Replacement: Randomized Clinical Trial Study

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ABSTRACT

Background: The standard approach for mitral valve surgery was a sternotomy, but with the new trends, mitral valve surgery can now be performed with right mini thoracotomy incision. Minimally invasive mitral valve surgery has demonstrated superior cosmetic outcomes, less surgical trauma, shortened intensive care unit and hospital stays, cost effectiveness, and faster recovery, while the efficacy is comparable to conventional sternotomy.

Objective: The aim of this research is to investigate the short-term outcomes of thoracoscopic minimally invasive mitral valve replacement in comparison with the conventional technique.

Subjects and Methods: This study included 100 patients with isolated mitral valve disease, who were randomly divided into two equal groups. Group A underwent a right anterolateral video-assisted mini-thoracotomy, while Group B was approached via a conventional median sternotomy.

Results: The minimally invasive group had significantly longer total operative time (291.3±48.89 min vs. 227.68±49.18 min, $p = 0.001$). However, Group A demonstrated better post-operative outcomes, including shorter ICU stay (2.1±1.07 vs. 3.82±1.49 days, $p = 0.002$), shorter extubation time (4.24±1.12 vs. 8.45±4.55 hours, $p = 0.0001$), reduced post-operative blood loss (271.7±107.09 ml vs. 449.2±230.93 ml, $p < 0.0001$). Post-operative pain scores were significantly lower in Group A (VAS 3.84±1.53 vs. 7.58±1.62, $p < 0.0001$), and hospital stay was shorter (7.22±1.37 vs. 11.21±3.53 days, $p < 0.0001$).

Conclusions: Minimally invasive mitral valve surgery can be a safe and effective alternative to traditional MVS in patients with mitral valve disease.

Introduction

Mitral valve disease (MVD) is one of the most common cardiac disorders, caused by malfunction of the valve that controls blood flow from the left atrium into the left ventricle. The disease may result in mitral valve stenosis, mitral valve regurgitation, or both. Rheumatic heart disease is the most common cause of mitral valve stenosis, whereas mitral valve regurgitation can result from degenerative changes, infective endocarditis, and ischemic heart disease. MVD is a major global health burden, especially in developing countries where rheumatic heart disease is still a leading

cause. When untreated, it can lead to complications such as heart failure, pulmonary hypertension, arrhythmias and increased mortality [1].

Conventional mitral valve surgery (MVS) over the last few decades is performed through a median sternotomy, which provides great exposure of the heart and mitral valve. This method, however, carries high surgical trauma, postoperative pain along with prolonged recovery period. Minimally invasive mitral valve surgery (MIMVS) has become an alternative approach to conventional sternotomy in recent years. MIMVS has smaller incisions, in many instances via a right mini-thoracotomy, allowing for thoracoscopic assistance for access to the mitral valve. It reduces the surgical trauma, postoperative pain, and recovery time while achieving outcomes at least equal to traditional sternotomy [2].

The history of MIMVS dates back to the late 1990s when surgeons began exploring less invasive techniques to reduce the morbidity associated with traditional sternotomy. Over time, advancements in surgical instruments, imaging technology, and cardiopulmonary bypass techniques have made MIMVS a viable option for many patients. Indications for MIMVS include isolated mitral valve disease, particularly in younger patients with fewer comorbidities. Contraindications may include severe peripheral vascular disease, previous right chest surgery, right ventricular dysfunction or complex mitral valve pathology requiring extensive repair [3].

Despite its advantages, MIMVS presents unique challenges, particularly in terms of cardiopulmonary bypass management and myocardial protection. These challenges necessitate specialized surgical expertise and careful patient selection to ensure optimal outcomes. The choice between MIMVS and conventional sternotomy often depends on patient-specific factors, including age, comorbidities, and the complexity of the mitral valve pathology [4].

Study aims to evaluate the short-term outcomes and 30-days mortality in thoracoscopic minimally invasive versus traditional mitral Valve replacement.

Subjects and Methods

Study Design and randomization

This randomized clinical trial study was carried out at Cardiac Surgery Department, National Heart Institute, Giza, Egypt, from September 2018 to October 2020. A total of 100 patients diagnosed with isolated mitral valve disease (MVD) who underwent mitral valve replacement (MVR) were randomly assigned to two equal groups. Group A comprised 50 patients who underwent MVR through a right anterolateral video-assisted mini-thoracotomy, representing a minimally invasive approach. In contrast, Group B included 50 patients who underwent conventional median sternotomy. To ensure that patients were equally divided between the groups, randomization was carried out using a computer-generated sequence in the Rj Editor module of Jamovi software (Version 2.4.8.0). Blinding was not possible because of the surgical procedure; hence the research was carried out as an open-label trial.

Inclusion and Exclusion Criteria

Patients were selected according to defined inclusion and exclusion criteria. The study exclusively involved patients undergoing isolated MVR, thereby excluding any involvement of the tricuspid valve. Patients were excluded if they had concomitant aortic valve disease, ischemic heart disease, contraindications to femoral cannulation, peripheral arterial disease, or a history of right lung surgery or radiotherapy to the right chest. Reoperation cases were excluded to preserve homogeneity in baseline characteristics. Also, pediatric age group and emergency cases were excluded.

Preoperative Assessment

All patients included in this study received a full preoperative assessment, that included history, physical examination, full labs, ECG, and chest imaging. Full detailed transthoracic and transesophageal echocardiography evaluation was performed to assess mitral valve pathology. CT aortogram and carotid duplex ultrasonography were performed in selected cases, especially for patients over 60 years, to assess vascular integrity and confirm eligibility for femoral cannulation. Preoperative risk stratification was conducted using EuroSCORE, a validated prediction model for assessing mortality risk in patients undergoing cardiac surgery. EuroSCORE considers patient-related factors (e.g., age, comorbidities), cardiac-related factors (e.g., NYHA classification, left ventricular function), and procedural risk variables to provide a risk score that categorizes patients into low, middle, and high-risk groups[5]. Due to its predictive accuracy, EuroSCORE was employed in our study to provide a uniform evaluation of surgical risk profiles for both minimally invasive and conventional sternotomy groups. The New York Heart Association (NYHA) functional classification system, an established method for evaluating heart failure degree depending on symptoms and physical activity restrictions, was utilized to classify patients [6].

Surgical Technique

All surgeries were performed under general anesthesia using double-lumen endotracheal intubation by a single surgeon assisted by the same team. During the operation cardiac functions were monitored by transesophageal echocardiography and deairing during weaning from CPB assisted with cardiac functions monitoring. In Group A, femoro-femoral cannulation was inserted, and the vacuum-assisted venous drainage was used to enhance the venous drainage and reduce the likelihood of retrograde aortic dissection. The surgical approach involved a 5–7 cm right anterolateral mini-thoracotomy, with additional 1 cm incisions for thoracoscopic camera placement, an atrial retractor, and a Chitwood aortic cross-clamp (Figure 1). The pericardium was opened with care to preserve the phrenic nerve, and the mitral valve was accessed through a left atrial incision. Cardioplegia was administered via an aortic cannula following cross-clamping of the ascending aorta, allowing for safe valve replacement. After MVR, atrial closure, deairing, weaning from CPB, decannulation, and hemostasis were performed, with rib adaptation using Vicryl sutures and chest tube placement as required.

Postoperative Assessment

Postoperatively, patients were closely monitored for ICU and hospital stay duration, ventilatory support, arrhythmias, cerebrovascular events, the need for inotropic support or mechanical circulatory assistance and complications such as bleeding, wound infection, and thromboembolic events. Other parameters assessed included postoperative pain scores, the need for blood transfusion, cosmetic satisfaction, and time to return to normal activities.

Follow-Up

Follow-up was conducted for up to one year postoperatively through clinic visits and telephone consultations to assess long-term outcomes and patient satisfaction.

Ethical Approval

Ethical approval for the study was obtained from the Institutional Review Board (IRB), and written informed consent was obtained from all participants before enrollment.

Statistical Analysis

Statistical analysis was performed using Jamovi software (Version 2.4.8.0). Qualitative variables were expressed as frequencies and percentages, with comparisons made using the Chi-square test, while quantitative data were presented as means ± standard deviation (SD) and analyzed using the student's t-test. A p-value of <0.05 was considered statistically significant.

Results

This study compared the outcomes of MVR performed using a minimally invasive right anterolateral video-assisted mini-thoracotomy (Group A) versus the conventional median sternotomy approach (Group B). A total of 100 patients were randomly assigned to either group.

Preoperative Patient Characteristics

The demographic data and preoperative clinical characteristics of the study population are summarized in Table 1.

Table 1: Preoperative Patient Characteristics.

Variable	GroupA(n=50)	GroupB (n=50)	P-value
Demographic Data			
Age (Mean±SD)	41.12 ± 11.54	44.82 ± 12.29	0.124
Gender n (%)			0.817
- Males	13 (26%)	12 (24%)	
- Females	37 (74%)	38 (76%)	
BMI (Mean±SD)	25.80 ± 4.73	24.75 ± 4.59	0.261
NYHA Classification			0.129
Class I	7 (14%)	4 (8%)	
Class II	19 (38%)	25 (50%)	
Class III	20 (40%)	18 (36%)	
Class IV	4 (8%)	3 (6%)	
Average NYHA Class	2.42 ± 0.83	2.4 ± 0.73	
Pre-Operative Echocardiographic Data	(Mean±SD)		
EF (%)	58.54 ± 6.48	61.52±7.02	0.030
ESD (cm^2)	3.56 ± 0.57	3.23 ± 0.67	0.012
EDD (cm^2)	5.25 ± 0.70	5.07 ± 0.85	0.256
LA (cm^2)	5.27 ± 0.87	5.23 ± 0.86	0.774
PASP (mm/hg)	48.34 ± 14.50	47.64±12.53	0.797

BMI – Body Mass Index, NYHA – New York Heart Association classification, EF – Ejection Fraction, ESD – End Systolic Diameter, EDD – End Diastolic Diameter, LA – Left Atrium, PASP – Pulmonary Artery Systolic Pressure.

Operative Findings

The intraoperative parameters showed significant differences between the two surgical techniques. The mean total bypass time (TBT) was significantly longer in Group A (146.12 ± 29.79 min) compared to Group B (109.48 ± 25.00 min, p = 0.001). Similarly, the mean cross-clamp time (CCT) was longer in Group A (108 ± 18.54 min) versus Group B (79.70 ± 19.73 min, p = 0.001). The total operative time (TOT) was also significantly longer in the minimally invasive group (291.3 ± 48.89 min) compared to the sternotomy group (227.68 ± 49.18 min, p = 0.001). (Table 2)

The length of the surgical incision was considerably smaller in Group A (7.44 ± 1.16 cm) compared to Group B (19.18 ± 2.32 cm, p = 0.001), confirming the minimally invasive nature of the procedure. (Figure 2)

Table2: Comparison of Intraoperative Parameters Between Minimally Invasive and Conventional Sternotomy Approaches.

Variable	Group A	Group B	P-value
Total Bypass Time (min)	146.12±29.79	109.48±25.00	0.001
Cross-Clamp Time (min)	108 ± 18.54	79.70±19.73	0.001
Total Operative Time (min)	291.3 ± 48.89	227.68±49.18	0.001
Surgical Incision Length (cm)	7.44 ± 1.16	19.18 ± 2.32	0.001

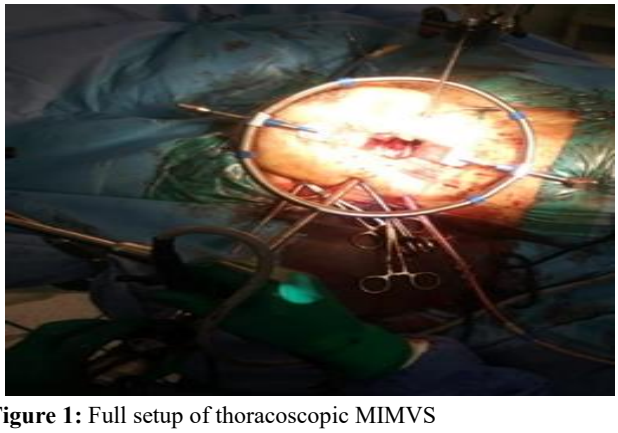

Figure 1: Full setup of thoracoscopic MIMVS

Figure 2: The length of the surgical incision

Postoperative Outcomes

Postoperative recovery metrics showed significant differences between the two groups. Group A had a shorter time to extubation, shorter ICU stay, lower postoperative blood drainage, and lower blood transfusion requirements compared to Group B (p-values < 0.05 for all parameters). These findings suggest that Group A had a faster recovery and less postoperative complication than Group B. (Table 3)

Table 3: Postoperative Recovery Metrics Comparison Between Group A and Group B

Variable	Group A	Group B	P-value
Time to Extubation (hours)	4.24±1.12	8.45±4.55	0.0001
ICU Stay Duration (days)	2.1 ± 1.07	3.82±1.49	0.002
Postoperative Blood Drainage (mL)	271.7±107.09	449.2±230.93	<0.0001
Blood Transfusion (units)	0.12 ± 0.43	0.6 ± 0.95	0.029

Postoperative Complications

There was no statistically significant difference in the overall incidence of postoperative complications between the two groups. Arrhythmias occurred in 6 patients (12%) in Group A and 7 patients (14%) in Group B (p > 0.05). Wound infections were observed in 4 patients (8%) in Group A and 6 patients (12%) in Group B (p > 0.05) (Figure 3). One case of left ventricular systolic dysfunction (EF = 40%) was reported in Group A, whereas Group B had one case of complete heart block requiring a permanent pacemaker. One mortality rate was recorded in Group B due to right-sided heart failure, while no mortality were reported in Group A. (Table 4)

Table 4: Post-operative complications of both groups.

	Group A n (n%)	Group B n (n%)	Significance p-value
Arrhythmias	6 (12%)	7 (14%)	>0.05
Wound infection	4 (8%)	6 (12%)	>0.05
LV systolic dysfunction	1 (2%)	0	>0.05
Heart block	0	1 (2%)	>0.05

Figure 3: Post-operative wound infection in minimally invasive group.

Follow-up Echocardiographic Findings

Echocardiographic evaluation at six months postoperatively revealed no significant differences in left ventricular dimensions, left atrial size, or pulmonary artery systolic pressure (PASP) between the two groups. (Table 5)

Table 5: Follow up echocardiography in both groups.

Variable	Group (A)		Group (B)		
	(Mean±SD)	Range	(Mean±SD)	Range	P-value
EF (%)	55.72±6.30	40-70	56.31±3.88	50-65	0.578
ESD(cm^2)	3.58±0.48	2.8-4.9	3.38±0.52	2.54.5	0.052
EDD(cm^2)	5.29±0.66	4.2-6.5	5.04±0.71	3.46.9	0.085
LA (cm^2)	4.9±0.54	4-6.5	5.19±0.94	3.37.4	0.058
PASP (mm/hg)	43.36±9.57	25-70	42.38±10.67	2067	0.633

Ejection Fraction (EF), End Systolic Diameter (ESD), End Diastolic Diameter (EDD), Left Atrium (LA), Pulmonary Artery Systolic Pressure (PASP).

Operative Costs and Cost-Effectiveness

While the total operative costs were higher for Group A than for Group B, the overall cost-effectiveness of the minimally invasive technique was evident in the significantly shorter ICU stay, less hospital stay, lower transfusion requirements, and improved postoperative recovery metrics. (Table 6)

Hospital Stay and Pain Scores

The total hospital stay duration was significantly shorter in Group A compared to Group B. The postoperative pain score (VAS scale) on the fifth postoperative day was significantly lower in Group A than in Group B, indicating a clear advantage of the minimally invasive approach in terms of patient comfort and recovery. (Table 6)

Table 6: Total hospital stays, postoperative pain, and operative costs between both groups.

Variable	Group A	Group B	P-value
Total Hospital Stay (days)	7.22±1.37	11.21±3.53	<0.0001
Postoperative Pain (VAS, Day 5)	3.84±1.53	7.58 ± 1.62	<0.0001
Total Operative Costs (USD)	6578±295.6	5728±365.18	<0.0001

Discussion

The results of this study highlight the superiority of minimally invasive mitral valve surgery (MIMVS) over conventional sternotomy in terms of short-term recovery, including reduced postoperative pain, shorter ICU and hospital stays, and less blood loss. These findings align with previous studies that have demonstrated the

advantages of MIMVS in reducing surgical trauma and promoting faster recovery [2,4]

In our study, the mean age of patients undergoing mitral valve replacement was 41.12 ± 11.54 years in Group A and 44.82 ± 12.29 years in Group B, indicating a relatively younger patient population compared to other studies. Grossi et al. reported an average age of 58 years in patients who had undergone MIMVS. The younger population in our study is likely due to the high incidence of rheumatic heart disease (RHD) in developing nations, which still largely contributes to mitral valve disease [7].

The left ventricular ejection fraction (LVEF) was nearly equivalent in both groups after surgery and showed no statistically significant differences. This corresponds to the results given by Cao et al., who noted preserved LVEF in patients who underwent MIMVS. It is essential to protect cardiac function, and our results show that the invasive procedure does not compromise the myocardial function [8].

The smaller incision size noted in Group (A) is in accordance with the principles of minimally invasive surgery aimed at lessening surgical incision. Furthermore, less surgical trauma likely results in reduction in postoperative ventilation time coupled with blood loss and the amount of required transfusions. These results in line with a meta-analysis conducted by Al Shamry., where MIMVS was associated with less blood loss and lower transfusion requirements in comparison to conventional sternotomy [4].

The short duration of ICU and hospital stays in Group A indicates a relatively quicker recovery. This has considerable impact on patient turnover and the spending of healthcare resources. These findings are also supported by Pojar et al., who showed that patients who had MIMVS had reduced hospital stays when compared to patients who had conventional surgery [9].

Even with the benefits noted, it is important to recognize the longer times for CPB and cross-clamp in the minimally invasive group. This has been noted in previous studies which have explained the prolonged times in MIMVS set by the complexities and the learning curve of the technique. Nevertheless, these times are likely to shorten with the experience gained by surgical teams [10].

With regards to complications, we noted that Group A had a lower arrhythmia incidence of 12% in comparison to the 20% new-onset atrial fibrillation incidence noted by Modi et al., while analyzing MIMVS outcomes [11]. Moreover, our study noted strokes in none of the cases of the minimally invasive approaches, though some other studies have documented low, yet notable, rates of stroke; for example, Ko et al., noted 0.3% stroke in his cohort [12]. The absence of stroke in our study may be attributed to meticulous surgical technique and patient selection.

When comparing our results to recent literature, a meta-analysis by Eqbal et al., found that minimally invasive approaches to MVS are associated with similar mortality and morbidity rates as conventional sternotomy, with the added benefits of reduced hospital stay and faster recovery. These findings are in line with our observations, further supporting the viability of minimally invasive techniques [13].

From a clinical standpoint, the lower postoperative pain scores in Group A further suggest that minimally invasive techniques are associated with improved patient comfort. This is an important finding, as it aligns with the growing emphasis on patient-centered care, which prioritizes minimizing postoperative pain and improving the overall patient experience [4].

This study has several limitations. The sample size is relatively small, and the follow-up period is limited to early postoperative outcomes. Long-term outcomes and potential late complications were not assessed. Additionally, the study was conducted at a single center, which may limit the generalizability of the findings.

Conclusion

In conclusion, our findings suggest that minimally invasive MVR via a right anterolateral video-assisted mini-thoracotomy is a safe and effective alternative to conventional median sternotomy.

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Conflict of Interest

Authors declare no conflict of interest.

Data availability

Data are available upon reasonable request.

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