Minimally Invasive Versus Conventional Median Sternotomy in Mitral Valve Replacement Surgery: A Single Center Experience

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Abstract
Background: Median sternotomy has been well established as the standard approach for mitral valve surgery. The rapid development of techniques over the past decade had led to the realization that the minimally invasive approach enables complex mitral valve surgery to be performed with good results.
Patients and Methods: 44 patients with mitral valve disease were included in a prospective comparative study. The patients were allocated randomly into : group (A) had mitral valve replacement through the minmally invasive right anterolateral minithoracotomy approach; and group (B) had mitral valve replacement through conventional median sternotomy approach. All patients were followed up for the assessment of the postoperative outcome.
Results: The final analysis included 22 patients in each group. A statistically significant difference was detected in skin incision length (9.77 ± 1.38 cm in group A and 16.32 ± 1.25 in group B), Intra-operative blood loss (168.64 ± 67.42 ml in group A and 286.36 ± 49.62 ml in group B) and total operation time (169.71 ± 69.94 in group A and 226.8 ± 79.6 in group B). There was a statistically significant difference regarding postoperative blood loss (256.82 ± 78.0 ml in group A and 470.91 ± 231.56 ml in group B). Group A showed significantly ($P < 0.0001$) less need for ICU stay duration (2.5 ± 0.74 days) and shorter hospital stay duration (7.73 ± 2.27 days). Additionally, patients in group A experienced lower pain score (9.18 ± 3.71).
Conclusion: Mitral valve surgery through minimally invasive anterolateral thoracotomy approach offers better outcomes over the conventional median sterontomy approach in aspects of intra-operative time and blood loss, skin incision length, postoperative blood loss, ICU and hospital stay duration, and pain score.

Keywords: median sternotomy, mitral valve surgery, minimally invasive, limited anterolateral thoracotomy.

Introduction

Median sternotomy has been considered as the standard approach for different open heart surgeries for many years. However, the full sternotomy incision has disadvantages like its length, post-operative pain and possible complications like sternotomy wound infection and dehiscence(1).

Sternal dehiscence following sternotomy may result in deep sternotomy wound infections (mediastinitis). Sternotomy wound bleeding is an important predisposing factor for sterntomy infections, that may lead to mortality and morbidity. (2)
The less invasive surgical procedures have gained preference by cardiothoracic surgeons over the past decade and multiple cardiac operations can be performed through these approaches. Minimally invasive

techniques in cardiac operations require higher surgical skills to accomplish the same quality compared with the traditional procedures with cardio-pulmonary bypass (CPB) or sternotomy(3).
Although mitral valve surgery has been performed via a full sternotomy incision, variety of techniques have enabled the surgeons to perform the mitral valve surgery through one or more small incisions in the thorax. Right limited anterolateral thoracotomy is one of the most popular approaches. It offers excellent and effortless exposure(4,5).
Efforts to minimize surgical trauma, hasten patient recovery, increase patient satisfaction, and reduce cost, without any compromise to surgical repair or replacement techniques, continue to be the rationale for minimally invasive procedures (6).
However, many factors affect the outcome of the minimally invasive procedures. These include the pre-operative status of the patient, the presence of any comorbidities, the severity of disease, and experience of the respective surgeons as well as the centers providing this treatment (7)**.**
We conducted this study to compare the intraoperative complications and the early postoperative outcome of the minimally invasive right anterolateral thoracotomy approach versus the median sternotomy approach for mitral valve replacemet.

Materials and Methods

Ethical Statement

The institutional review board (IRB) - Zagazig University; was obtained and the number of approval is (10433/12-2-2023). A written informed consent was signed from all patients included in the study.

Study Design and Population

The study was held at the Cardiothoracic Surgery Department at Zagazig University Hospitals, in the duration from December 2022 to July 2023.
All patients who were candidates for isolated mitral valve replacement were included in this study.
The exclusion criteria were patients who had combined valve disease, patients with significant Ischemic heart disease, patients with preoperative cardiogenic shock or cardiopulmonary resuscitation, Patients with chest or vertebral wall deformities and patients who had infective endocarditis.
Finally, 44 patients were included in our study. They were randomly allocated into 2 equal groups. Limited right anterolateal thoracotomy approach group A (n = 22) and Median sternotomy approach group B (n = 22). The randomization process was performed by one of the authors other than the surgeons who operated the patients. using a computerized program where the odd numbers were added to group A and the even numbers were added to group B.

Surgical Technique

Two cardiothoracic surgeons with an experience over 10 years operated all patients.

Antibiotic Prophylaxis

1 gm cefazolin was administered within 60 minutes as an intravenous infusion over 30 minutes before the skin incision for all patients.

Surgical technique

Group “A” (anterolateral thoracotomy approach)

Patients were positioned supine with the right hemithorax elevated 45 degrees and the right arm is positioned at the patient’s side. The mid axillary line (MAL) is exposed on right side. Patients in this group were intubated using a double lumen endotracheal tube. It was replaced by a single lumen endotracheal tube after completion of the surgical procedure and just before the transfer of the patient to the intensive care unit.
The landmarks were correctly identified (sternum, Xiphisternum and the 4th intercostal space). The incision was extended laterally from the nipple over the fourth intercostal space; above the nipple in males and in the inframammary crease in females; and extended for about 7-12 centimeters in length.

The pericardium was incised under direct vision 2 centimeters anterior to the phrenic nerve and was extended superiorly to the aortic reflection. The pericardium was tucked to incision edges using silk sutures, to present the heart rotated counter-clockwise. Thus, displacing the left atrium laterally and ventrally allowing direct-vision and access to the aortic origin, atriocaval junction, and right superior pulmonary vein.

Cannulation& Initiation of CPB

Cannulation of the femoral artery and femoral vein was performed before mediastinal dissection.

TEE guidance was mandatory in all patients to ensure correct intraluminal direction of the venous cannula and it was manipulated by expert anesthetist. An antegrade cardioplegia and vent cannula was inserted in the ascending aorta. Antegrade crystalloid cardioplegia was used in addition to systemic cooling to 28 celesius degrees in addition to iced saline bath to keep the myocardium temperature at 15 celesius degrees. The ascending aorta was occluded with an external clamp.

After cardiac arrest on cardiopulmonary bypass, the left atrium was incised just next to the interatrial groove allowing optimum view. Mitral valve replacement was performed in a standard fashion.

After completion of the mitral valve replacement, the left atrium was closed followed by weaning from cardiopulmonary bypass as usual. A DC Shock was administered using the pediatric paddles if the heart continued to fibrillate.

Group "B" (median Sternotomy approach)

The patient was positioned supine. Intubation was done by single lumen endotracheal tube. The operation was performed through the conventional median sternotomy approach and on cardiopulmonary bypass.

In both groups, the muscle and soft tissue layers were closed carefully in an anatomical fashion. Patients were transferred on mechanical ventilator to postcardiac surgery intensive care unit. Inotropic support was added if needed.

Postoperative Follow-Up

All patients were carefully evaluated during their stay at intensive care unit: blood loss and replacement, need for re-exploration, laboratory investigations and weaning from the mechanical ventilator. Follow up was continued during their hospital stay in the ward in the form of : Sternotomy wound examination, routine laboratory investigations, pain score, plain chest X-ray and the length of hospital stay duartion.

The details of VAS was categorized as described by Boswell et al. as the following: the range of pain was measured from 0 to 100 where score 0 is for no pain and score 100 is for the worst possible pain (8). Pain score was recorded on post-operative day 7.

Statistical analysis:

Data was collected, verified and edited on a personal computer then analyzed by using SPSS (Statistical package for the social science) version 20.0. the used tests were Chi-square (X2) test of significance, Fisher Exact and independent T-test. Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. All statistical comparisons were two tailed with significance Level of P-value < 0.05 indicates significant while, $P > 0.05$ indicates Non-significant difference.

Results:

This prospective randomized controlled clinical trial was conducted at Cardiothoracic Surgery Department, Zagazig University Hospital, spanning from December 2022 to July 2023. This study was to compare the procedure and the outcome of the standard sternotomy approach versus the minimally invasive approach through right anterolateral minithoracotomy.

Results of our study showed no significant difference ($p>0.05$) between both studied groups regarding the demographic data (table 1).

Patients in both studied groups showed no significant difference in the preoperative Newyork Heart Association (NYHA) classification (table2).

Table 3 presents the preoperative echocardiogram findings in patients included in both studied groups; there was no significant difference regarding mitral valve leaflets, valve opening, pressure gradient across the valve, left atrium size, left ventricle, and the enlargement of right heart.

The intraoperative data and complications are shown in table 4. A significant difference was detected between both groups regarding the following data: aortic cross clamp time was 89.76 ± 43.8 minutes in group A and 102.7 ± 21.3 minutes in group B, total bypass time was 120.8 ± 29.87 minutes in group A and 148 ± 38.8 in group B and total operation time was 169.71 ± 69.94 minutes in group A and 226.8 ± 79.6 minutes in Group B.

Additionally, A highly significant statistical difference (p value <0.0001) is detected in length of skin incision where it was 9.77 ± 1.38 cm in group A and 16.32 ± 1.25 cm in group B. Moreover, The intraoperative blood loss was significantly lower in patients included in group A (168.64 ± 67.42 ml) than in patients included in group B (286.36 ± 49.62 ml) (Table 4).

Patients were admitted to the intensive care unit on mechanically ventilated. After stabilization of the patients, they were transmitted to the ward for care and rehabilitation. Table 5 presents the postoperative course and complications in both studied groups. Group A showed significantly lower postoperative blood loss (256.82 ± 78.03 ml) compared to group B (470.91 ± 231.56 ml). The difference was statistically significant (P value = 0.00018) highlighting that minimal invasive procedures resulted in less blood loss. The patients in group A had a significantly shorter stay in the ICU (1.7 ± 0.32 days) compared to the sternotomy group (2.19 ± 0.77 days) where the P value is calculated 0. 00861.

Additionally, Patients in group A has experienced a significantly (P value < 0.0001) lower pain score (9.18 ± 3.71) compared to patients in group B (35.23 ± 8.52). There is highly significant statistical difference (P value = 0.00001) between both groups regarding the length of hospital stay, where it was shorter in group A (7.73 ± 1.27 days) compared to group B (10.77 ± 2.52 days).

No statistical significant difference was detected between both studied groups regarding the need for re-exploration, wound infection and early postoperative death. One case of postoperative mortality in group B, however, the cause was due to neglected hypothyrodism and it was not related to the surgical approach.

Table (1): Demographic data among included subjects in both study group

	Minimally invasive group (N = 22)	Sternotomy group (N = 22)	P. Value
Age	43.32 ± 13.1	46.64 ± 12.45	0.39413
Sex			
Male	7 (31.82%)	8 (36.36%)	0.7505
Female	15 (68.18%)	14 (63.64%)	0.75727
Comorbidities			
Hypertension	12 (54.55%)	11 (50%)	0.7628
Diabetes Mellitus	10 (45.45%)	14 (63.64%)	0.5397
COPD	13 (59.09%)	11 (50%)	0.5448

Abbreviations: COPD:chronic obstructive pulmonary disase.

Table (2): NYHA Classification in patients of both studied groups

NYHA classification	Minimally invasive group (N = 22)	Sternotomy group (N = 22)	
I	6 (27.27%)	4 (18.18%)	0.4718
II	6 (27.27%)	5 (22.73%)	0.7278
III	8 (36.36%)	11 (50%)	0.3612
IV	2 (9.09%)	2 (9.09%)	>0.99

Abbreviations:NYHA: New York Heart Association

Table (3): Echocardiography data recorded on preoperative assessment

Echocardiography data	Minimally invasive group (N = 22)	Sternotomy group (N = 22)	
Thickening and calcification of the mitral valve leaflets	8 (36.36%)	3 (13.64%)	0.0817
Restricted valve opening	13 (59.09%)	11 (50%)	0.5448
Increased pressure gradient across the valve	13 (59.09%)	11 (50%)	0.5448
Enlarged left atrium	22 (100%)	22 (100%)	>0.99
Abnormal retrograde flow of blood	9 (40.91%)	11 (50%)	0.5448
Dilation of the left ventricle	5 (22.73%)	4 (18.18%)	0.7086
Right heart enlargement	4 (18.18%)	5 (22.73%)	0.7086

Table (4): Intra-operative course among patients included in both study groups

	Minimally invasive group (N = 22)	Sternotomy group (N = 22)	P. Value
Total bypass time (min.)	120.8 ± 29.87	148 ± 38.8	0.01264*
Aortic cross clamp time (min.)	89.76 ± 43.8	102.7 ± 21.3	0.21961
Length of skin incision (cm)	9.77 ± 1.38	16.32 ± 1.25	<0.0001*
Intra-operative blood loss (ml)	168.64 ± 67.42	286.36 ± 49.62	<0.0001*
Total operation time (min.)	169.71 ± 69.94	226.8 ± 79.6	0.01535*

Table (5): Post-operative outcome and complications among patients included in both study groups

	Minimally invasive group (N = 22)	Sternotomy group (N = 22)	P. Value
Postoperative blood loss	256.82 ± 78.03	470.91 ± 231.56	0.00018*
ICU stay duration	2.5 ± 0.74	3.91 ± 1.15	0.00002*
Pain Visual Analogue Scale	9.18 ± 3.71	35.23 ± 8.52	<0.0001*
Total hospital stay	7.73 ± 2.27	10.77 ± 5.52	0.00002*
Complications			
Re-exploration	0 (0%)	1 (4.55%)	0.98
Wound infection	5 (22.73%)	8 (36.36%)	0.3216
Death	0 (0%)	1 (4.55%)	0.98

Abbreviations:ICU:intensive care unit

Discussion

Mitral valve replacement (MVR) surgery is a critical procedure performed to treat severe mitral valve diseases, such as stenosis and regurgitation. Traditionally, this surgical intervention has been accomplished using the conventional median sternotomy approach, where a large incision is made down the center of the chest to access the heart(9).

The emergence of minimally invasive mitral valve replacement techniques has gained attention in the recent years due to their potential to minimize trauma and faster recovery. These procedures typically entail smaller incisions, facilitating more targeted and precise surgeries. Worthy benefits of the minimally invasive approach include reduced blood loss, minimized scarring, decreased risk of sternal complications,

and shorter hospital stays. Moreover, the anesthetic advantages associated with this technique may positively impact patients' psychological well-being post-surgery (10,11).

It is important to mention that the safety and efficacy of the surgical procedure is a cornerstone in each surgical procedure. Although some studies have reported shorter hospital stays and lower rates of wound complications with the minimally invasive approach, a comperehensive and long-term investigations are still needed for the evaluation of the technique. We conducted this study to evaluate the efficacy of the minimally invasive right anterolateral thoracotomy approach in comparison to the conventional median sternotomy approach for mitarl valve replacement. We aimed to assess the intraoperative course and the early postoperative outcome on patients.

Regarding the demographic data, we found no significant difference in age and sex distribution between the minimal invasive and sternotomy groups. In the Minimally Invasive Group, the average age was approximately 43.32 years (SD = 13.1) with female predominance (68.18%). In the Sternotomy Group, the average age was approximately 46.64 years (SD = 12.45 with female predominance as well (63.64%) with no significant difference between the two groups. There were non-significant difference in comorbidities such as hypertension, diabetes mellitus, and COPD between both groups.

The higher prevalence of mitral valve disease among females in both surgical groups may be attributed to hormonal differences, including the cardioprotective effects of estrogen, autoimmune disorders more common in females, and genetic predisposition. Moreover, in both studied groups, there was a higher proportion of patients classified as NYHA (New York Heart Association) Class III, indicating marked limitation of physical activity due to symptoms like dyspnea and fatigue. This finding can be explained by the severity of mitral valve disease in these individuals, leading to functional impairment of the heart. Comorbidities such as hypertension, diabetes mellitus, and ischemic heart disease in patients with mitral valve disease can be linked to structural and functional changes in the heart, impacting valve integrity and contributing to cardiovascular dysfunction (12,13).

On preoperative echocardiography assessment, the left atrium was found enlarged in all patients, indicating similar severity of mitral valve disease. A higher incidence of thickening and calcification of the mitral valve leaflets in group A was detected, however it shows non- significant difference compared to group B.

The higher incidence of mitral valve leaflet thickening and calcification in the minimal invasive group compared to the Conventional Median Sternotomy group may be attributed to the restricted access and reduced visibility during the procedure, potentially leading to increased trauma and stress on the valve leaflets. Furthermore, Patient selection could also play a role, as certain characteristics of patients chosen for the minimal invasive approach may make their valve leaflets more susceptible to thickening and calcification (14,15).

In their study, **Moscarelli et al.** compared the outcomes of minimally invasive mitral valve surgery with standard sternotomy. The results showed that the minimally invasive approach was associated with some favorable outcomes, including a lower rate of atrial fibrillation. Moreover, **Cheng et al.** study had demonstrated a significant reduction in atrial fibrillation with minimal invasive mitral valve surgery, indicating that this less traumatic surgical approach may lead to a lower risk of arrhythmia. The reduction in atrial fibrillation observed in their meta-analysis suggests that the minimal invasive technique might result in lesser inducement of inflammatory mediators, contributing to improved cardiac rhythm outcomes (16,17).

In our study, group A had a significantly shorter ischemic time, shorter total cardiopulmonary bypass shorter time total operation time, less length of skin incision, and less intra-operative blood loss. The reduced blood loss is likely due to the smaller incisions, which result in less tissue trauma and bleeding.

Regarding postoperative evaluations and outcomes on our study, we found that the postoperative outcomes demonstrated several advantages for the minimally invasive group. Patients who underwent the minimal invasive procedure had significantly lower postoperative blood loss, shorter ICU stay, reduced pain intensity (lower VAS score), and a shorter total hospital stay. These benefits can be explained by the reduced tissue trauma and faster recovery associated with minimal invasive procedures, leading to improved patient outcomes and quicker discharge from the hospital.

In the study conducted by **Eltonsy et al.**, they found that the total operation time was significantly shorter in the minimal invasive group compared to the conventional approach. They also reported reduced blood loss and lower postoperative chest tube drainage in the minimally invasive group. Additionally, their study, found lower postoperative pain scores and reduced blood transfusion rates in the minimal invasive groups (18).

Sündermann et al. in their analysis of over 20,000 patients from 46 studies, they found that the MIVS procedure was associated with a longer cardio-pulmonary-bypass time, longer cross-clamp time, and longer mean procedure length compared to conventional surgery. They also reported that resource-related outcomes like length of hospital stay and length of stay at the ICU were in favor of minimally invasive valve surgery (MIVS), with shorter stays for MIVS patients (19).

Svensson et al. also observed that the mini-thoracotomy technique required less postoperative morphine dosages than the conventional technique, indicating reduced postoperative pain in the minimal invasive group (20).

Cheng et al. had conducted a meta-analysis and they reported that minimally invasive mitral valve surgery (MMVS) may be associated with fewer blood product transfusions, shorter length of hospital stay, and rapid return to normal activity (17).

Daemen et al. had compared the right anterior thoracotomy with conventional sternotomy. They reported that the right anterior thoracotomy approach was associated with shorter hospital length of stay (21).

The findings reported by **Speziale et al.** supported the minimally invasive mitral valve surgery (MIMVS) as the standard surgical approach for the treatment of mitral valve disease. When comparing MIMVS to full-sternotomy mitral valve surgery, they found that MIMVS was associated with several advantages like reduced postoperative bleeding with a lower incidence of re-exploration, decreased postoperative pain, a lower incidence of deep wound infection, shorter intensive care unit (ICU) stay, and improved cosmoses (22).

The study by **Pojar et al.** evaluated data from 525 patients who underwent mitral valve surgery, with 189 patients undergoing minithoracotomy and 336 patients undergoing median sternotomy. There were no significant differences in the incidence of stroke, surgical site infections, myocardial infarction between the two groups. However, the minimally invasive approach was associated with fewer patients receiving blood components transfusions (59% versus 76% in the conventional group) and a lower rate of reoperation for bleeding (3% versus 9%) (23).

Other studies did not detect significant differences in mortality between minimally invasive approaches and conventional sternotomy (RR: 0.5, 95% CI: [0.1−5.4]). However, they suggested that the association between MMVS and lower mortality in observational studies was likely due to bias (24).

moreover **Moscarelli et al. and Eqbal et al.** compared the outcomes of minimally invasive mitral valve surgery with standard sternotomy. The results showed that the mortality rates were comparable between the two approaches ($p = 0.19$ and $p = .97$ respectively) (25,26).

Conclusions

Mitral valve replacement through the minimally invasive limited right anterolateral thoracotomy approach offers a safe and an effective technique. It clearly shows less intraoperative time and complications. Moreover, the postoperative course in the operated patients through the minimally invasive approach shows less postoperative blood loss, shoretr ICU and hospital stay duration, less wound complications and less pain score. Thus, the minimally invasive right anterolateral thoracotomy approach should be considered when possible for patients requiring mitral valve replacement.

Limitations of the study

We think that the small sample size and short time for the postoperative follow up of the included patients may be considered as limitation for this study. However, we are aiming in the near future at introduction of a larger study to enable us to study more details of the intraoperative and potoperative coure of the patients.

Ethical Approval

Institutional review board approval was obtained.

Informed Consent

Written informed consent was obtained from all patients.

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