Minimal Invasive Mitral Valve Surgery Postoperative Pulmonary Complications

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ABSTRACT

Background: Postoperative pulmonary complications (PPCs) are not uncommon events that lead to long hospital stay, readmissions into the intensive care unit (ICU), high costs, and death after cardiac surgery. **Objective:** Our research compares the prevalence of postoperative lung complications between minimally invasive mitral valve surgery (MIVS) and tradiotional full median sternotomy (FS) approach. **Methods:** 100 patients underwent isolated mitral valve surgery (50 MIVS through thoracotomy and 50 FS) in our institution between January 2020 and January 2022. Propensity score-matching analysis was used to compare outcomes between the groups and to reduce selection bias. **Results:** The incidence of PPCs was insignificantly less in the MIVS group than in the FS group. The most common PPCs were atelectasis, pleural effusions, and pulmonary infection. Prolonged mechanical ventilation time (> 24 h), length of hospital stay, and ICU phase were significantly less in the MIVS group. Cardiopulmonary bypass (CBP), aortic cross-clamping, and operative times were significantly longer in the MIVS group than in the matched FS group (P < 0.001). **Conclusion:** MIVS for isolated valve surgery carries low risk of PPCs compared with the full sternotomy approach.

Keywords: Minimally invasive surgery, Mitral valve, Postoperative pulmonary complications, Full sternotomy.

INTRODUCTION

During the previous several decades of cardiac surgery, the majority of surgeries have been performed via median sternotomy with CPB. This paradigm is shifting, with cardiac surgery increasingly focusing on less invasive procedures. Advancements in patient diagnostics, surgical instruments, and operative approaches have enabled surgeons to execute a wide range of difficult surgeries through tiny incisions and, in some situations, without CPB[(1)].

Since the 90s of last century, the concept and practice of minimally invasive heart surgery has become more popular. Many variables have contributed to the development, including less surgical stress, less bleeding, less post-operative discomfort, faster healing, lower risk of infections, and the elimination of the potential of deep sternal wound infection or sternal non-reunion [(2)].

Unlike standard cardiac surgery, which necessitates a median sternotomy approach, minimally invasive cardiac surgery is heart surgery carried out through a variety of tiny incisions. Patients who were previously deemed at high risk for conventional surgery owing to age or medical history can now undergo heart surgery thanks to this method [(1)]. However, new patterns of complications are only beginning to emerge;

pulmonary difficulties remain a primary source of post-cardiac surgery morbidity, extending hospital stays and increasing expenditures [(3)].

The elevated frequency of lung problems can be attributed in part to the interruption of normal ventilator function that occurs after chest surgery. Furthermore, patients who undergo such surgery frequently have major underlying conditions that increase their risk of PPCs[(4)].

The purpose of the research was to compare between minimal invasive mitral valve surgery and traditional median sternotomy on a range of clinical outcomes regarding pulmonary complications.

PATIENTS AND METHODS

This observational, prospective, one arm, single center clinical study was structured to compare between minimal invasive mitral valve surgery and traditional median sternotomy on a range of clinical outcomes regarding pulmonary complications. This study involved 120 patients with cardiac disease who were all candidates for mitral valve surgery comparing between minimal invasive mitral valve surgery and traditional median sternotomy regarding pulmonary complications during their hospital stay from January 2020 to January 2022.

Inclusion criteria: Indication for interventional mitral valve surgery (minimally invasive and traditional median sternotomy) to the current available evidence regarding this management; Ability to provide an written consent after abundant discussion for all info for the current study,

Exclusion criteria: Patients with history of previous cardiac surgery, patients with history of previous thoracotomy, patients with chest wall deformities, Patients with severely calcified iliac-femoral and thoraco-abdominal aorta arteries should not have femoral artery cannulation because they provide a risk of embolic events from retrograde perfusion, patients undergoing combined procedures as mitral valve surgery and CABG or ascending aortic aneurysm and patients with urgent cardiac surgery.

Patients are examined for participation in an all-comers design after presenting to the heart team, a group of surgeons, and interventional cardiologists, and reaching an agreement.

This non randomized study included 120 patients who underwent mitral valve surgery divided into 2 groups: 60 patients of minimal invasive surgery and 60 patients of traditional median sternotomy, Comparing between 2 groups regarding pulmonary complications.

The study was at: Kasr Al Ainy Hospital; Kasr Al Ainy pediatric hospital; Kasr Al Ainy affiliated hospitals and Beni_suef University hospital. Preoperative assessment and preparation:

History taking: A thorough and detailed history taken, concerning the age, sex, functional class according to New York Heart Association (NYHA) classification.

Clinical examination: full clinical general and local cardiological examination was performed.

Lab Studies: Complete Blood Count, kidney function tests, liver function tests, electrolytes Evaluation and respiratory function tests (RFTs).

A spirometric study was done the day before the procedure, in the morning, while sitting with the nasal clip on.

Imaging Studies: Coronary angiography, transthoracic Echocardiographic examination (TTE), bilateral lower limb arterial duplex (For femoral vessel cannulation) and CT chest.

Preoperative meeting: A brief description of the surgical steps, post-operative events, and ICU stay will be provided during the preoperative visit prior to surgery. The visual analogue scale for pain evaluation in the postoperative phase is explained to patients during the preoperative session. Preoperative preparation: All patients were given their morning dosage of cardiac medicines. All patients received intramuscular 10-mg morphine sulphate before being transferred to the operating room.

Anesthesia approach: Each patient had the same surgical anesthetic technique, which included the insertion of a 20 gauge artery cannula under local anesthesia in the non-dominant radial. Fentanyl 100–200 µg is administered again based only on need. Following complete muscular relaxation, the trachea was intubated via the mouth using a suitable endotracheal tube (a twin lumen tube was used for patients undergoing minimally invasive procedures). All patients' anesthesia is maintained by inhaling 0.5-0.1% isuflorane.

TEE in minimally invasive cases was a mandatory step manipulated by anesthetist.

Cardiopulmonary bypass (CPB) membrane oxygenators were employed. During CPB, the hemocrite level is maintained at around 28%.

Surgical technique Group “A” (MIMVS): Patients are supine, with the right arm at the patient's side exposing the mid-axillary line on the right side and the right shoulder raised 30 to 50 degrees. A double lumen endotracheal tube or an endobronchial blocker inserted into the right mainstem bronchus was used to intubate these patients.

Incision: The incision is done just adjacent to the nipple over the fourth intercostal space (above the nipple in men and in the lower breast crease in majority of women) 7-12 cm in length.

Figure (1): Right mini-thoracotomy.

The pericardium is incised 2-cm anterior to the phrenic nerve under direct vision and extended upwards to the aortic reflection.

The posterior pericardial border has three lateral sutures for retraction. The first is attached to the lateral corner of the skin incision and takes over the right superior pulmonary vein. A 12-gage needle, a tiny hook, and a small clamp are used to penetrate the second through the chest wall and secure the suture halfway to the diaphragm. The mid-ascending aorta's medial pericardium is fastened to the posterior sternum to expose the ascending aorta so that the aortic clamp may be installed; the third suture is placed at the level of the superior vena cava and is carried through the third intercostals gap as laterally as feasible. Cannulation and CPB Initiation Cannulation of the femoral vein and artery should occur before mediastinal dissection in order to start CPB. A little 3- to 4-cm transverse incision is made in the groin between the inguinal ligament and the inguinal crease to perform femoral arterial cannulation.

Figure (2): Femoral Cannulation.

Using a guidewire and TEE guidance, the femoral venous cannula is placed into the superior vena cava.

The femoral venous cannula is generally placed first. In order to improve superior vena caval drainage, the anesthesia team also inserts a 17 fr percutaneous cannula into the right internal jugular vein. After that, the femoral artery tapes are loosened and the 5-0 polypropylene tourniquets are fastened to ensure that the leg is constantly perfused around the cannula.

Figure (3): Aortic cross clamping.

After cardioplegia given on CPB, Adjacent to the interatrial groove, the left atrium is opened. When utilizing a minimally invasive atrial retractor, it is possible to execute intricate repairs on the mitral valve and subvalvular apparatus because to the typically good view of the left atrium and mitral valve. Following the completion of the mitral surgery, the left atrium is closed conventionally, and a left ventricular vent is passed via the incision made in the left atrium, the mitral valve, and the left ventricle.

The percutaneous venous cannula is simply withdrawn. Closing the pericardium was done by interrupted sutures over a drain after placement of pacing wires.

Group "B" (Sternotomy)

The patient is in a supine position, arms by his or her sides. A sandbag is positioned beneath the shoulders. Drapes are placed as normal, exposing the sternum up to the midclavicular line and at least one groin. Palpation is used to identify the sternal notch and the tip of the xiphoid process, and the incision is made around 2 cm below the sternal notch and extends roughly 2 cm past the distal end of the xiphoid process before being diathermically prolonged down to the sternal periosteum. The sternum was extended only as much as required to get proper exposure. The left innominate vein is visible once the thymic gland is dissected, revealing the pericardium. Most of the time, enough exposure is achieved by using strong silk stay sutures and sewing the pericardium to the wound's margins. Aortobicaval cannulation is then done and on aortic root cannula is put for cardioplegia solution infusion and deairing.

Figure (4): Traditional full sternotomy.

After initiating CPB, the procedure is comparable to the less invasive anterolateral minithoracotomy group.

The sternum was then re-united using six to nine thick stainless-steel wires that were threaded through it. The subcutaneous tissue is then closed with continuous absorbable 2/0 sutures, and the skin is closed with 3/0 subcuticular suture.

Operative Data and Parameters: Following presentation to the heart team, which included cardiac surgeons and interventional cardiologists, and agreement, patients were examined for participation in an all-comers framework.

A record was made of the following: Operative technique, ischemic time, total CPB time, any occurrence of surgical problems necessitating full sternotomy and need for intraoperative inotropic support.

Postoperative follow-up: A standard record of postoperative data was applied. A record was made of the following: ICU stay, mechanical ventilator support and if it was prolonged, mean hospital stay, pulmonary function tests and operative morbidity

Operative morbidity: all pulmonary complications during their hospital stay as: Atelectasis of deflated lung, barotrauma when reinflating the lung, increased incidence of need for prolonged ventilation, phrenic nerve injury, Pleural effusion, pulmonary edema, pneumonia, lung herniation and wound complications and sepsis.

Potential risks: Intraoperative Shift to traditional full sternotomy incision.

Study outcomes:

Primary outcomes: As for any cardiac surgery small percentage of patients carry the risk of: renal complications, neurological complications, prolonged ventilation and death. Secondary outcome parameters: Morbidity associated (pulmonary complications): atelectasis of deflated lung, barotrauma when reinflating the lung, increased incidence of need for prolonged ventilation, phrenic nerve injury, pleural effusion, pulmonary edema, pneumonia and lung herniation.

Ethical Considerations:

Written full information consent, was written by all participants, study was in accordance with scientific ethical committee of Kasr Al Ainy, Cairo University. Study was approved by scientific ethical committee of Kasr Al Ainy, Cairo University.

Statistical analysis:

Microsoft Excel 2010 database (Microsoft Corporation) and R version 3.2.4 (The R Foundation for Statistical Computing) are used to collect and analyze the data; R Studio is used in conjunction with these tools to do statistical analysis and create graphs and diagrams. In continuous data containing outliers, the Wilcoxon exact test was utilized as a more reliable substitute for the t-test. The number of patients whose DLCO improved following surgery was tested for significance using the binomial test. A linear model was employed to compare the improvement in sPAP and DLCO, respectively, among the patient groups. A statistically significant value was defined as $p < 0.05$.

RESULTS

Table (1): Baseline characteristics of the studied patients:

Characteristics	**Group A (n=60)**	**Group B (n=60)**	**P- value**
Age (mean ± SD)	33.200±11.186	31.983±8.879	0.511
Sex			
Males	36(60.0%)	26(43.3%)	0.068
Females	24(40.0%)	34(56.7%)	

*P-value is significant

There was no significant difference between both groups concerning their age and sex distribution. Table (1).

Table (2): Mitral valve pathology of the studied patients

Characteristics	**Group A**	**Group B**	**P- value**
Mitral pathology			
-Severe MR	12(20.0%)	16(26.7%)	
-Severe MR & moderate MS	9(15.0%)	11(18.3%)	
-Severe MS	24(40.0%)	6(10.0%)	0.001*
-Severe MS& moderate MR	7(11.7%)	24(40.0%)	
-Severe MS & severe MR	8(13.3%)	3(5.0%)	

*P-value is significant

Mitral stenosis was significantly prevalent in group B. This table showed that there was no significant difference between the 2 groups in terms of the Echo parameters (this indicated that both groups were matched). Figure (5) & Table (2).

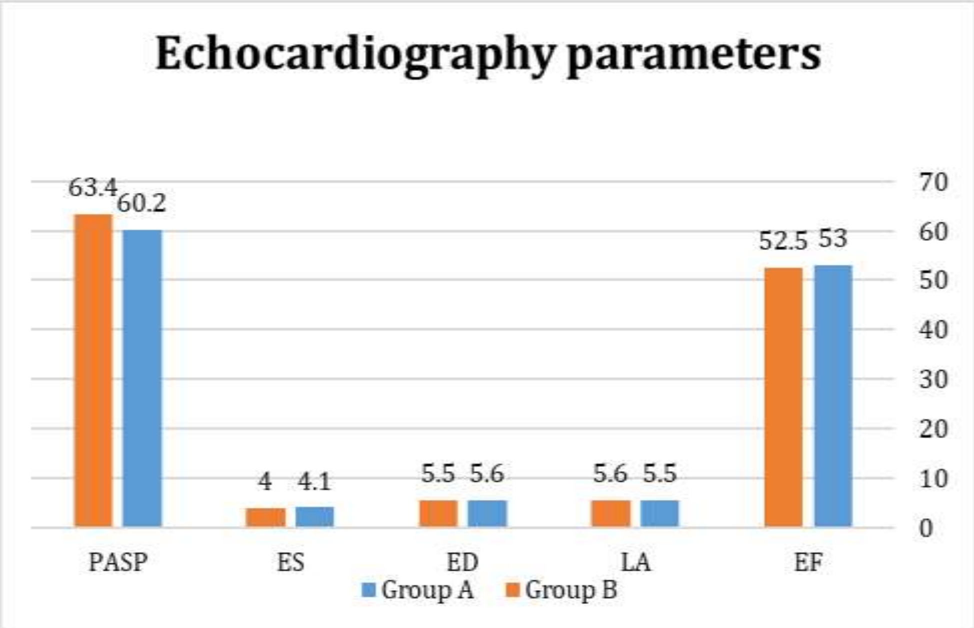

Figure (5): Ecchocardiography parameters.

Table (3): Post-operative pulmonary function tests of the studied patients:

Characteristics	Group A (n=60)	Group B (n=60)	P- value
FEV1	2.133±0.384	1.995±.164	0.067
FVC	2.104±0.304	1.910±0.218	0.055
FEV1/FVC	1.010±0.148	0.997±0.197	0.688

*P-value is significant

There was an insignificant higher FEV1 and FVC in group A than group B, and the FEV1/FVC ratio didn't differ significantly between both groups (Pvalue=0.688). Table (3).

Table (4): Intra-operative parameters of the studied patients:

Characteristics	Group A (n=60)	Group B (n=60)	P- value
Clamp time	63.2±12.8	60.9±11.4	0.065
Bypass time	107.6±17.5	87.2±14.2	<0.001*
Need for shift to traditional median sternotomy: *Bleeding *Difficult femoral cannulation	2(3.33) 1(1.66) 1(1.66)	0 (0) 0(0) 0(0)	0.155
Need to inotropes	60(100)	60(100)	---
Type of surgery (Mitral valve repair)	1(1.66)	2(3.33)	0.559

*P-value is significant

There was insignificant higher clamping time and significant higher bypass time in group A than group B (P-value<0.001). There was no significant difference between both groups regarding shift to traditional median sternotomy, need to inotropes and type of surgery (P-value0.05). Table (4).

Table (5): Follow up of pre- and post-operative pulmonary function tests of group A

Group A	Pre-operative	Post-operative	P- value
FEV1	3.030±0.273	2.132±0.384	<0.001*
FVC	3.98±0.275	2.104±0.304	<0.001*
FEV1/FVC	0.766±0.089	1.010±0.148	<0.001*

*P-value is significant

There was a significant decline of FEV1, FVC and increase of FEV1/FVC ratio in group A after the operation (P-value<0.001). **Table (5).**

Table (6): Follow up of pre- and post-operative pulmonary function tests of group B:

Group B	Pre-operative	Post-operative	P- value
FEV1	3.025±0.287	1.795±.164	<0.001*
FVC	3.968±0.305	1.810±0.218	<0.001*
FEV1/FVC	0.764±0.099	0.997±0.197	<0.001*

*P-value is significant

There was a significant of decline of FEV1, FVC and increase FEV1/FVC in group B after the operation (P-value<0.001). **Table (6).**

There was a significant higher percentage of decline of FEV1 and FVC in group B than group A (P-value<0.001), but the FEV1/FVC ratio percentage of change didn't differ significantly between both groups (P-value=0.973). **Figure (6)**

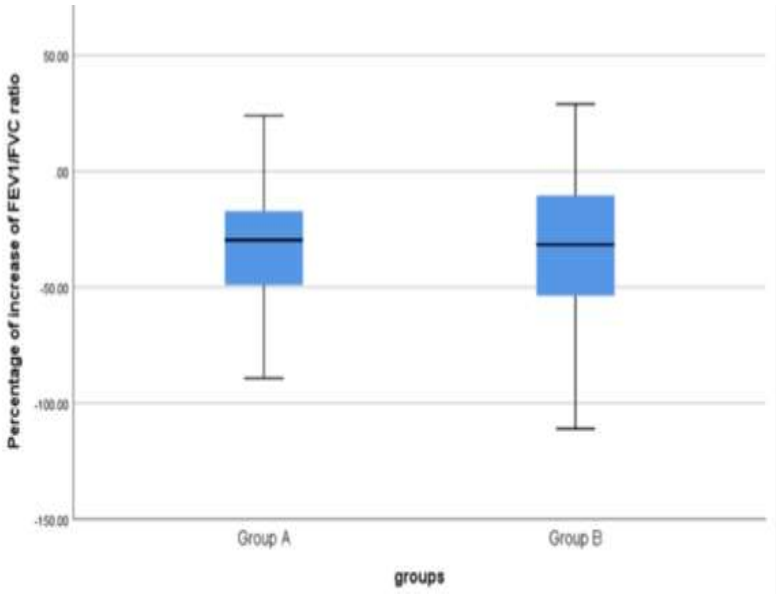

Figure (6): Comparison between both groups regarding the percentage of decrease of FEV1/FVC ratio.

There was insignificant longer duration (hours) on mechanical ventilation and significant higher hospital stay in group B than group A(P-value<0.001), but the length of stay in ICU didn't differ significantly between both groups (P-value=0.937). **Figures (7, 8)**

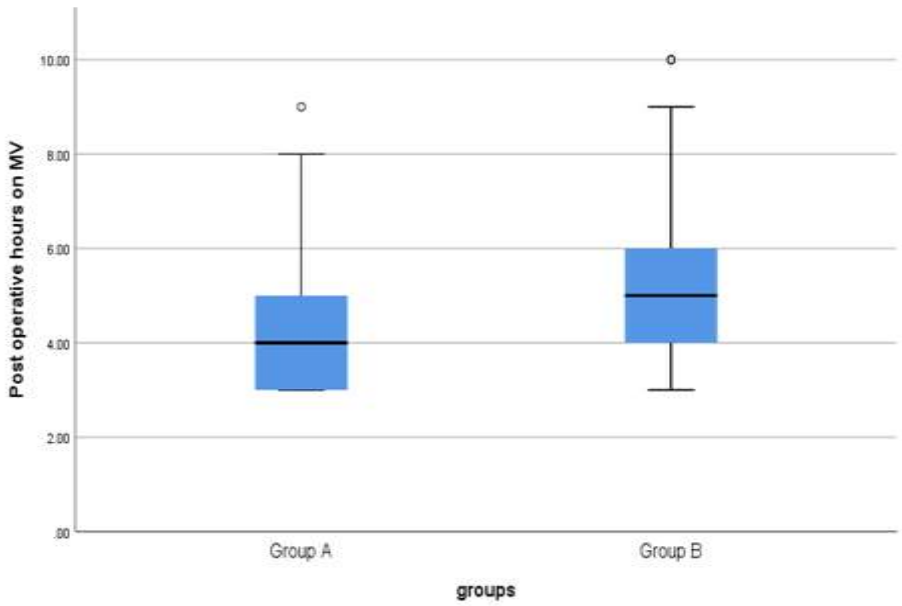

Figure (7): Comparison between both groups regarding the hours on MV.

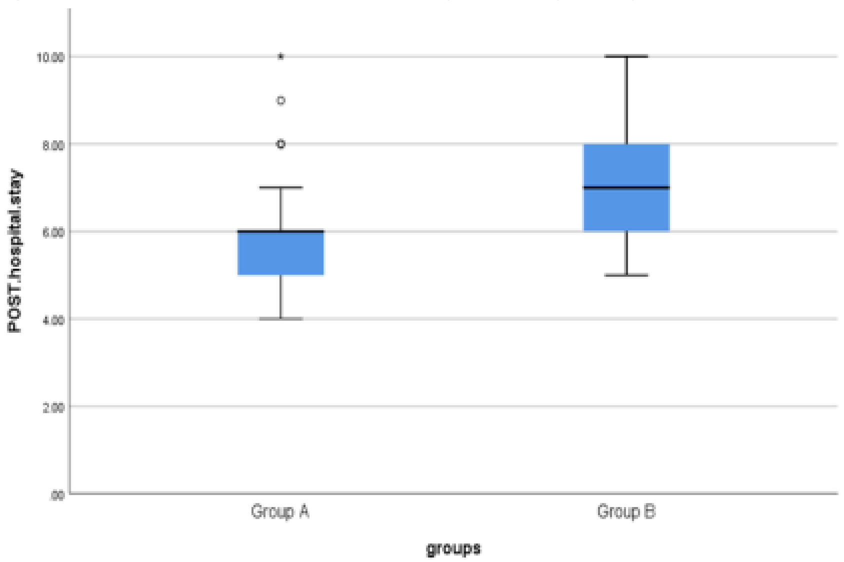

Figure (8): Comparison between both groups regarding the hospital length of stay.

Table (7): Comparison between the 2 groups in regard of post-operative pulmonary complications.

Characteristics	Group A 60 patients	Group B 60 patients	P- value
Atelectasis	3 (5%)	7 (11%)	0.455
Barotrauma	0	0	>0.999
Phrenic nerve injury	0	0	>0.999
Wound infection	1 (1.7%)	3 (5%)	0.317
Lung herniation	0	0	>0.999
Pneumonia	0	1 (1.7%)	0.312
Pleural effusion	1 (1.7%)	1 (1.7%)	>0.999

*P- value is significant

There was insignificant increase of atelectasis in group B than group A, and the other complications didn't differ significantly between both groups (P-value>0.999). Table (7).

DISCUSSION

Our research emphasized that patients undergoing isolated Mitral valve procedure, a minimally invasive technique had less incidence of multiple complications and had better outcomes, although minimally invasive approaches had prolonged aortic cross-clamping and CBP times and longer operative time.

Regarding Age In our study, the mean age in group "A" was 33.200±11.186 years, while in group "B", it was 31.983±8.879 years. The age groups in our study are relatively younger than the age groups in other studies. **Grossi et al.** [5] reported a mean age of 55.3 ± 13.6 years, also in other studies as **Mohamed et al.** [6] and the mean age was above 50 years. The younger mean age in our dataset might be attributable to early and recurring infection with rheumatic fever, which is common in most poor countries, including Egypt. There was no statistically significant difference in the mean ages of our research groups.

Regarding sex, 55% of patients were males and 45% were females. This shows that the female affection is less than the male affection. **McClure et al.** [7] reported that sex distribution is 80% females and 20% males which is reflective of rheumatic mitral affection. There was no statistically significant difference between sex distributions in our study groups.

The preoperative echocardiographic evaluation in our study showed that in group "A" there was 36patients (60%) suffered from isolated mitral valve pathology either stenosis or regurge, and 24 patients (40%) had double mitral valve disease (regurge and stenosis). In group "B" there was 16 cases (36%) suffered from isolated mitral valve pathology and 44 patients (64%) had double mitral valve pathology without statistical significance between the two groups, the ejection fraction (EF) in group "A" was 53.000±5.554 % while in group "B" it was 52.550±7.299 %. In **McClure et al.** [7], study showed that EF 60.4±10 is nearly equal for our study.

No statistical difference between the 2 groups, however several studies showed that patients with a small left atrium are more easily approached through the left lateral prone position as the posterior position of the mitral valve provides excellent access and vision with minimum amount of retraction of the separator. The surgeon also has the valve right in front, which allows for more comfortable surgery even in patients with small left atrium [6].

Clamping time in our study there was insignificant higher clamping time and significant higher bypass time in group A than group B (P-value0.05). The total bypass time in group "A" was 107.6±17.5 min while in group "B" it was 87.2±14.2 minutes. Cross clamp time in group "A" was 63.2±12.8 min while in group "B" it was 60.9±11.4 minutes.

Bypass time: These data show that the time from weaning from the CPB to the end of the operation was significantly lower in group "B". One of the downsides of the correct mini-thoracotomy strategy is that it requires great experience from the surgeon and team to be able to complete the surgery through a smaller incision in less time [8, 9, 10, 11].

In our investigation, the group (A) patients received cannulation of the femoral artery and vein, which was done by a tiny 3- to 4-cm transverse incision in the groin between the inguinal crease and the inguinal ligament. The femoral cannulation was smooth in all patients except 1 patient we needed aortic cannulation due to small caliber of femoral artery. In another case we shifted to median sternotomy after declamping due to massive bleeding which we were not able to control through thoracotomy. The use of femoral artery cannulation for arterial blood input was documented in several research [10, 11].

Furthermore, we think that the restricted field and the aorta's relative inaccessibility for cannulation are the main drawbacks of right thoracotomy.

All patients in our study in both groups need Intraoperative inotropes which most of them were in small doses and stopped shortly in ICU like also **Mohamed et al.** [6].

Postoperative data:

ICU evaluation:

In our study, no attempt was done for extubating the patient in the operating theatre. All patients in both groups needed mechanical ventilation. The postoperative mechanical ventilation ranged from 4-10 hours with a mean of 4.417±1.418 hours in group "A". In group "B", the ventilation time was significantly higher and ranged from 6- 24 hours, with a mean of 4.733±1.712 hours. This denoting statistical insignificant increase in group B than group A, like **Sener et al. [8], El Fiky et al. [9], Kumar et al. [12], Wang et al. [13] and Srivastava et al. [14]** studies showed that postoperative MV is significantly lower in patients undergoing MIVS.

ICU stay:

The mean stay in the ICU in group "A" was 2.483±0.854 days, while in group "B" the mean stay was 3.083±1.510 days, although the ICU stay was less in group "A", yet it had no statistically significant difference due to limited number of cases. In a study done by **Sener et al. [8]**, the mean ICU stay in minimal invasive group was 1.78± .832 days while in the sternotomy group it was 2.1 ± 0.564 days. Most of the studies performed, showed that the mean ICU stay was less in the minimal invasive group.

Postoperative Spirometry performed to all patients. Our study showed that there was a significant decrease of FEV1, FVC in both groups but there was a significant higher percentage of decline of FEV1 and FVC in group B than group A (P-value less than 0.001), however the FEV1/ FVC ratio percentage of change didn't differ significantly between both groups (P-value = 0.973).

In group B pulmonary functions declined more than group A which was statistically significant and mostly patients suffered from restrictive pulmonary impairment. **Mohamed et al. [6]** showed Spirometry changes following a mitral valve procedure. This decrease in pulmonary function can be explained as a result of median sternotomy and CPB triggering inflammatory responses [15]. Also, **Gomaa et al.[16]** had shown that the FVC, FEV1, FVC%, and FEV1 % showed a very significant difference, whereas the FEV1/FVC did not significantly vary between the two groups, with group A patients who underwent less invasive surgery having improved post-operative lung function.

Our study recorded that there was insignificant increase of atelectasis in group B than group A, and the other complications didn't differ significantly between both groups (P-value>0.999). In group "A", there were patients with complications 5 cases (8%). In group "B", 12 cases (20%) suffered from post-operative complications.

After a cardiac procedure, postoperative atelectasis has been observed in 10% of patients, mostly in those with postoperative pulmonary dysfunction, which occurs in the majority of patients with postoperative pulmonary dysfunction following a cardiac operation. **Bonacchi et al. [17]** reported an incidence of 7.5% for postoperative atelectasis following MIVS, whereas 5% of patients in the current research experienced it. The use of continuous positive airway pressure (5 cm H2O) and positive endexpiratory pressure (7–8 cm H2O) during the postoperative mechanical ventilator phase may have contributed to the reduced incidence of atelectasis in group (A) in our research.

The primary danger to life for a surgical patient is still postoperative pneumonia, which typically coexists with atelectasis since pneumonia can result from many of the clinical alterations caused by atelectasis. After heart surgery, pneumonia has been documented to occur 2.0–2.7% of the time. In our research, 1.7% of individuals had postoperative pneumonia following matching.

Although **Gamil et al. [10]**, reported that the prevalence of wound infection is more in the sternotomy group and they attributed this finding to the fact that in smaller incisions, the potential for wound infection is less.

Total hospital stay:

Our study found that in group "A" had a mean hospital stay of 5.817±1.200 days, whereas group "B" had a mean hospital stay of 7.083±1.225 days. This difference is statistically significant, with a P value < 0.01. Furthermore, **Mohamed et al. [6]** observed a mean hospital stay of 5.9±2 days for patients undergoing thoracotomy and 8.8±3 days for those undergoing sternotomy.

CONCLUSION

Minimal mitral valve surgery may be safe regarding pain and return to normal activity, bleeding, sternal wound infection, dysrhythmias, neurological insults and scar satisfaction. In the direction of the expanding elderly population, MIMVS provides a successful surgical method for treatment of mitral valve disease with the potential for considerable resource reduction.

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