Comparative study between mitral valve surgery by the minimally invasive approach and traditional median sternotomy

Yasser Mubarak[a,b], Ayman M. Shaalan[c,d]

[a]Department of Cardiothoracic Surgery, Minia University, El Minya, [c]Department of Cardiothoracic Surgery, Faculty of Medicine, Benha University, Benha, Egypt, [b]Madinah Cardiac Center, King Fahd Hospital, Madinah, [d]Dallah Hospital, Cardiac Center, Riyadh, Saudi Arabia

Correspondence to Ayman M. Shaalan, MD, Department of Cardiothoracic Surgery, Faculty of Medicine, Benha University, Benha 13518, Egypt. Mob: +966509460403; e-mail: shalaanayman@yahoo.com

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Background
This study compares our experience of early surgical outcome for the mitral valve (MV) after minimally invasive surgery and traditional median sternotomy approach.
Aim
The aim of the study is to evaluate early surgical outcome of minimally invasive mitral valve surgery (MIMVS) in our experience.
Patients and methods
It is a prospective comparative cohort study in adult patients who perform MVS either MI or standard median sternotomy (SMS). From January 2019 to December 2021, early outcome of MVS between (120 patients) MI group through right minithoracotomy with cardiopulmonary bypass peripheral cannulation and 120 patients SMS group are compared.
Result
Females are more in MIMVS (80%). Blood loss is lesser in MIMVS (250 ± 60.6 ml) than in SMS (550 ± 230 ml). Blood transfusion required 0.1 ± 0.53 in MIMVS, and 0.9 ± 0.7 in SMS. Reexploration for bleeding is required in four cases of SMS. Mechanical ventilation time is shorter in MIMVS (6.4 ± 1.3) than in SMS (12.4 ± 6.8). ICU duration and hospital stay are shorter in MIMVS than SMS (2 ± 0.4 vs. 3.5 ± 1.3, 7.2 ± 1.3 vs. 12 ± 0.5). Wound infections were present in 20 cases of SMS. Spirometric studies in MIMVS reveal better postoperative pulmonary functions than the SMS group. Pain visual analog score at discharge is better in MIMVS (1.4 ± 0.6) than in SMS (8.5 ± 1.5).
Conclusion
Minimally invasive surgery for the MV showed satisfactory outcome in comparison to sternotomy approach. The need for rising curve of training for all surgeons is mandatory.

Keywords:
minimally invasive, mitral, thoracotomy

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Background

In spite of availability of the minimally invasive cardiac surgery (MICS) technique for long time ago, most of the cardiac surgeons remained reluctant to perform MICS [1]. Many obstacles included a learning curve and special instruments were required. Also, it had disadvantages of longer cardiopulmonary bypass (CPB) time, difficult visualization, and poor exposure of operative field [2]. Moreover, it carried a high risk of stroke because of inadequate deairing [3]. Difficult exploration in MICS was present in patients with average body weight; obese patients had more high surgical risk [4,5].

MICS was introduced to overcome morbidity associated with standard median sternotomy (SMS). Its access was achieved through right minithoracotomy (RMT). The advances in instruments and cannula systems had allowed surgeons to perform MICS easily. Moreover, there was a need to overcome limitations of increased CPB time, difficult deairing, and added more complex surgery [4].

The advantages of smaller surgical incisions were early recovery, less postoperative pain, better cosmesis, and carried low risk of wound infection [5,6]. With the MICS approach, risky cases benefit more from limiting surgical incision with this approach [4]. There are efforts to decrease incision length, enhanced recovery, and better patient satisfaction, without drawback on surgical techniques [7]. Improved cosmesis should be one of the indications for MICS as it added benefit [4].

Other benefits of minimally invasive surgery (MIS) included reduction in the incidence of bleeding, blood transfusion, and atrial fibrillation (AF) as well as better ICU and hospital stays [2]. Minimally invasive mitral valve surgery (MIMVS) had mortality rates of 1.2–5.8% [6].

Patients and methods

The current study included 240 consecutive patients who required mitral valve surgery (MVS). The study included cases from January 2019 to December 2021. Consents were taken from all patients after the procedure had been outlined in detail. Patients who had undergone MIMVS (*n*=120) compared with patients who had undergone SMS (*n*=120). MIMIVS was performed according to patients' acceptance and desire, if there were no contraindications. Demographic data and associated comorbidities are expressed in Table 1. Inclusion criteria were elective MVS. Exclusion criteria were mitral surgery with other concomitant cardiac surgery, emergency and redo surgery, endocarditis, ischemic mitral regurgitation, low EF (<30%), chest wall deformity, previous thoracotomy or thoracic radiation, chronic obstructive pulmonary disease [forced expiratory volume in 1 s (FEV1<1L)], and liver or kidney failure.

Ethics approval and consent to participate: consents from all patients and approval from the Ethics Committee of the two centers were obtained after explaining all operative details and all possible risk, Research Reference No. 2020 R103.Careful history for relevant data and comorbidities for patient selection for MIS is essential: clinical examination, echocardiography, pulmonary function testing (PFT), and coronary angiography when indicated. Preoperative computed tomography aortography provides valuable information regarding aortic aneurysm, tortuosity, atherosclerosis, and femoral artery suitability for cannulation.

All patient data such as CPB and aortic cross clamp times, mortality, and morbidity data (stroke, prolonged ventilation, bleeding, renal failure, and wound infection) were recorded. Sternal wound infection (SWI) either superficial SWI (including skin and subcutaneous) or deep SWI including sternal bone exposure with/without stability, necrotic bone, and heart exposure, with/without septicemia were collected.

Surgical technique

SMS group case exposures were done through traditional median sternotomy. Aorto-bicaval cannulation and on pump valve surgery were performed. However, the patients who underwent minimally invasive surgery (MIMVS) were anesthetized using a double-lumen tube under full monitoring in a supine position slightly tilted to the left. External defibrillator was connected. Intraoperative transesophageal echocardiography (TEE) was obtained for all the patients. CPB was performed through the peripheral cannulation technique. Arterial femoral cannulation was done using a 16–18 Fr arterial cannula, and femoral vein was cannulated with a 25 Fr cannula through the open technique. Two venous drainage cannulas were routinely used in our study. Superior vena cava cannula was inserted percutaneously from the neck (Fig. 1).

The MV was approached through right thoracotomy. A small incision (5–6 cm) was done through the fourth intercostal space. The soft tissue retractor and metallic multiuse retractors allow optimal exposure (Fig. 2a). Pericardiotomy was done anterior to the right phrenic nerve to expose the left atrium extending from the aorta to the diaphragm. Pericardial stay sutures were used for better exposure and small hooks (crochet) pulled the stay sutures outside the chest. To overcome the poorly visualized field, due to the high

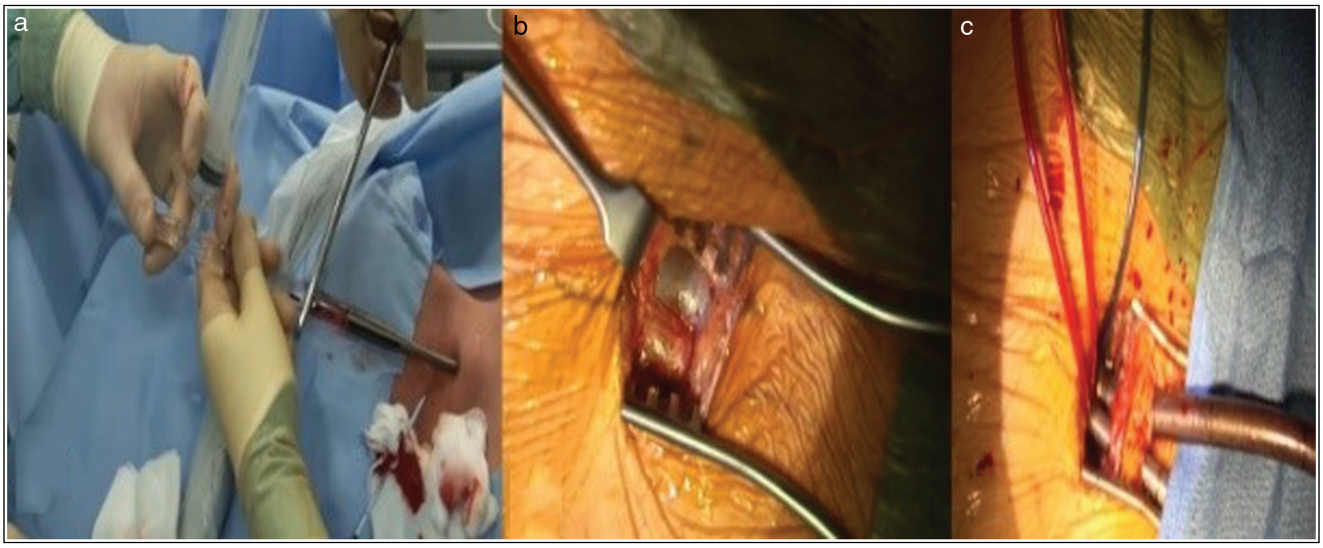
Table 1 Demographics and preoperative patient data

Variables	MIMVS (*N*=120) [*n* (%)]	SMS (*N*=120) [*n* (%)]
Age (mean±SD)	42.6±12.8	48.5±13.4
Female sex	92 (80)	24 (20)*
Diabetes mellitus	4 (3.3)	3 (2.5)
Body surface area (mean±SD)	1.7±0.1	1.67±0.1
Preoperative NYHA III	32 (26.7)	28 (23.3)
Preoperative NYHA IV	88 (73.3)	92 (76.7)
AF	30 (25)	36 (30)
LVEF % (mean±SD)	53.8±16.2	56.8±9.8
PASP (mmHg) (mean±SD)	48.9±18.7	43±15.3
Mitral valve pathology (case)		
Mitral stenosis	80 (66.7)	65 (54.2)
Mitral insufficiency	10 (8.3)	20 (16.7)
Mixed	30 (25)	35 (29.2)
Tricuspid regurgitation (case)		
Mild	90 (75)	80 (66.7)
Moderate	30 (25)	20 (16.7)
Severe	0	20 (16.7)

AF, atrial fibrillation; LVEF, left ventricular ejection fraction; MIMVS, minimally invasive mitral valve surgery; NYHA, New York Heart Association; PASP, pulmonary artery systolic pressure; SMS, standard median sternotomy.

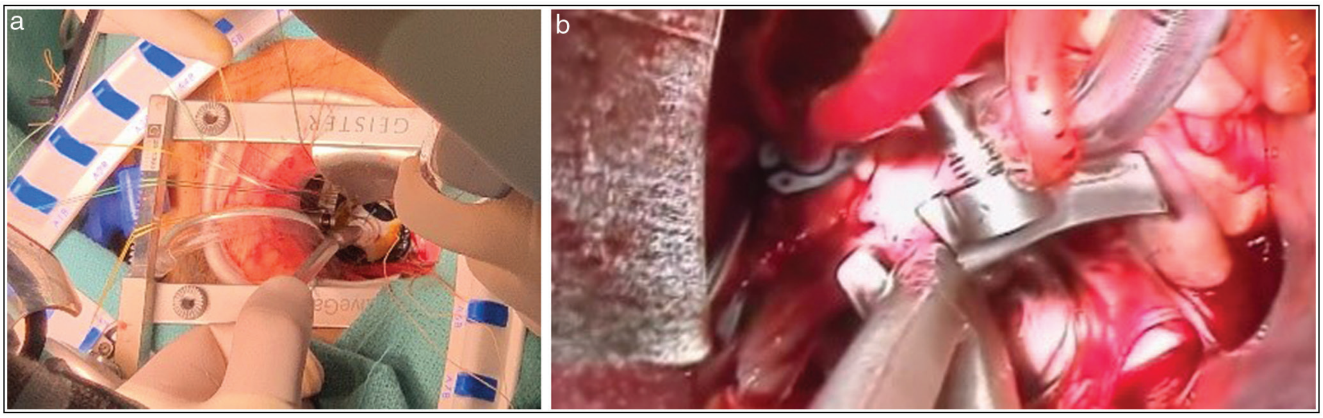
*Significant difference for female gender.

Figure 1



Peripheral cannulation in MIMVS (a) SVC cannulation in the neck. (b) femoral vessels exposure. (c) Femoral cannulation. MIMVS, minimally invasive mitral valve surgery; SVC, superior vena cava.

Figure 2



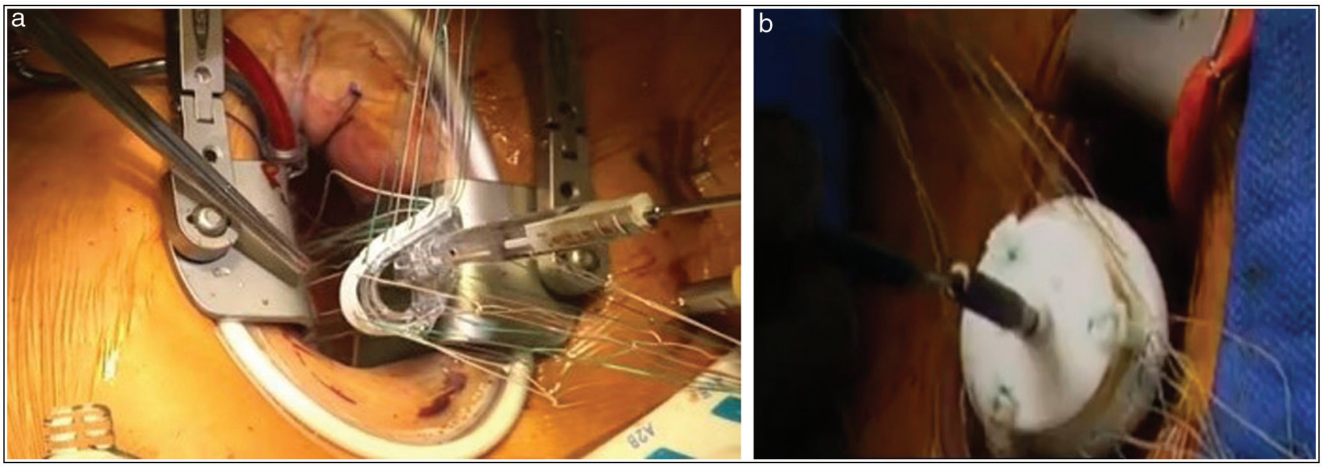
(a) MIMVS via RMT with soft tissue and multiuse rib spreader. (b) Atrial retractor through right parasternal small incision. MIMVS, minimally invasive mitral valve surgery; RMT, right minithoracotomy.

diaphragmatic dome, stay suture was stitched within the central tendon of the right diaphragmatic copula. A cardioplegia cannula was inserted into the ascending aorta. CPB was initiated with moderate hypothermia (32°C). Venous drainage was assisted by vacuum at40 mmHg. A Chitwood clamp was then inserted through a separate stab (Fig. 2b). Carbon dioxide flow was used to reduce the retained intracardiac gas. A special atrial retractor was used to obtain MV exposure. Atrial retractor blade of proper size was used to expose the MV. The retractor handle passed through a small incision at the right sternal margin lateral to the mammary vessels to be attached to the retractor blade. After completing the planned surgical procedure and left atrial closure was done (either valve replacement or repair), a pacing wire was inserted while the heart was empty and before releasing the aortic cross clamp (Fig. 3). Deairing was done while the patient was in Trendelenburg position, followed by filling of the heart and positive pressure ventilation, which is confirmed by TEE. Defibrillator in certain cases was needed (Fig. 4). After discontinuing CPB and protamine was given as protocol, decannulation femoral arteriotomy was sutured with 5/0 Prolene. The pericardium is closed with two to three single sutures. After hemostasis one or two (28 Fr) chest drains were inserted into the pericardium and the right pleural space. The thoracotomy incision was closed in the routine manner.

Statistical analysis

SPSS package was used (version 20.0; SPSS Inc., Chicago, Illinois, USA). The data were collected and analyzed after had been expressed as percentage,

Figure 3



(a) Mitral valve ring repair. (b) Mitral valve replacement with bilogical valve.

Figure 4

Defibrillator using small paddles through RMT. RMT, right minithoracotomy.

number, mean, and SD. Significant statistical data were noted if the *P* value is less than 0.05.

Result

Our study included 240 cases who were divided into two groups, MIMVS (*n*=120) was compared with patients who had undergone SMS (*n*=120). Demographic and preoperative patient data of both groups were insignificantly different except that MIMVS was more common in females (80%) (Table 1).

All data showed numerical variations, diabetes mellitus was documented in 3% MIMVS, 2% SMS and body surface area (1.7±0.1 MIMVS, 1.67±0.1 SMS). In the MIMVS group, New York Heart Association (NYHA) class III was documented in (*n*=32) 26.7% cases and NYHA IV in (*n*=88) 73.3% cases. On the second SMS group NYHA III was found in (*n*=28) 23.3% cases, while NYHA IV was documented in (*n*=92) 76.7% cases. AF (15 MIMVA, 18 SMS), EF (53.8±16.2 MIMVS, 56.8±9.8 SMS), and FEV1 (2.15±0.5 MIMVS, 2.7±0.6 SMS); there was no significant difference between both groups.

Table 2 Intraoperative data in both groups

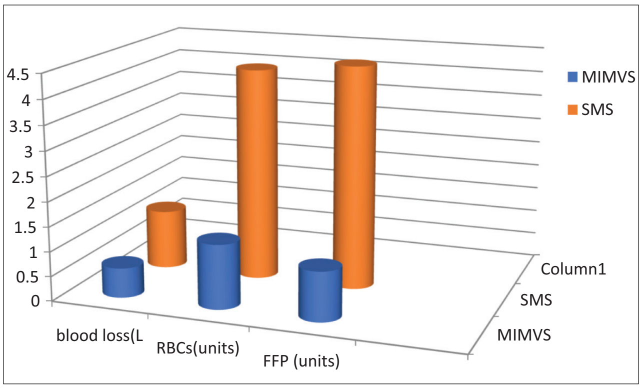
Variables	MIMVS (*N*=120) [*n* (%)]	SMS (*N*=120) [*n* (%)]
ACC time (min)	118±15.5	74.4±32.3*
CPB time (min)	155±28.5	115±48.8*
Mitral valve replacement (case)	112 (93.3)	110 (91.7)
Mechanical valve	100 (83.3)	100 (83.3)
Tissue valve	12 (10)	10 (8.3)
Mitral valve repair (case)	8 (6.7)	10 (8.3)
Tricuspid repair (case)	0	35 (29.2)* *N*=33 ring *N*=2 Miniband

ACC, aortic cross clamp; CPB, cardiopulmonary bypass; LAA, left atrial appendage; MIMVS, minimally invasive mitral valve surgery; SMS, standard median sternotomy.
**P* value less than 0.05 statistically significant.

Intraoperative data in both groups showed insignificant difference except that the tricuspid repair in the SMS group has a significant *P* value of less than 0.05 (Table 2). MV replacement (prosthetic or bioprosthetic valve) and repair were similar in both groups. However, after removal of cross-clamp tricuspid repair (ring or miniband) was done only in the SMS group regarding our experience in complex lesions with the minimally invasive technique.

In our study, postoperative data in both groups were showing more blood loss and more blood transfusion (Graph 1), high rate of wound infection, prolonged hospital stay, and more pain according to pain visual analog scale at the time of discharge in the SMS group (Table 3). Duration of mechanical ventilation, ICU, and hospital stay time were more in the SMS group (Graph 2).

Graph 1



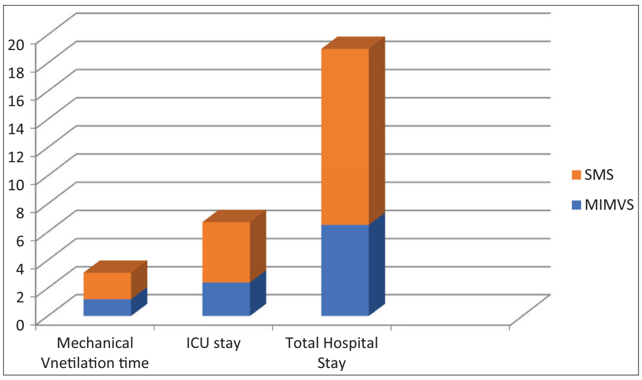
Blood loss and transfusion in two groups.

Table 3 Postoperative data in both groups

Variables	MIMVS (*N*=120) [*n* (%)]	SMS (*N*=120) [*n* (%)]
Wound infection	0	20*
Superficial	0	15
Deep	0	5
Pacemaker implantation	1 (0.8)	1 (0.8)
Blood loss (ml) in drains	250±60.6	550±230*
Blood transfusion	0.1±0.53	0.9±0.7
Reexploration for bleeding	0	4 (3.3)*
Mechanical ventilation time (h)	6.4±1.3	12.4±6.8*
ICU duration (days)	2±0.4	3.5±1.3
Length of hospital stay (days)	7.2±1.3	12±0.5*
Pain (VAS) at discharge	1.4±0.6	8.5±1.5*
Length of Incision	5–8 cm	15–20 cm*
	6.2±1.3	16.3±5.8

MIMVS, minimally invasive mitral valve surgery; SMS, standard median sternotomy; VAS, visual analog scale.
**P* value less than 0.05 statistically significant.

Graph 2



Duration of MV, ICU, and hospital stay time in both groups. MV, mitral valve.

Blood loss in MIMVS was 250±60.6 versus 550±230 in the SMS group, which showed significant statistical difference. Blood transfusion was 0.1±0.53 in the MIMVS group and 0.9±0.7 in the SMS group with significant difference, *P* value less than 0.05. Wound infection was seen in *n*=20 cases of the SMS group; there were [8] cases of superficial SWI and [5] cases of deep SWI that needed vacuum. Deep SWI had sternal bone exposed but still stable with positive culture (*Staphylococcus aureus*). In our study, length of incision was 6.2±1.3 cm in MIMVS and 16.3±5.8 cm in SMS with significant *P* value.

Table 4 Preoperative spirometric study in both groups

Variables	MIMVS (*N*=120)	SMS (*N*=120)
FVC (l)	2.54±0.67	2.91±0.83
FEV1 (l)	2.15±0.5	2.7±0.6
FEV1/FVC	89.14±5.8	91.75±3.8

FEV1, forced expiratory volume in 1 s; FVC: forced volume capacity; MIMVS, minimally invasive mitral valve surgery; SMS, standard median sternotomy.

Table 5 Postoperative pulmonary functions in both groups

Variables	MIMVS (*N*=120)	SMS (*N*=120)
FVC (l)	2.19±0.72	1.52±0.36*
FEV1 (l)	2.02±0.63	1.43±0.38*
FEV1/FVC	90.83±9.81	93.92±7.27

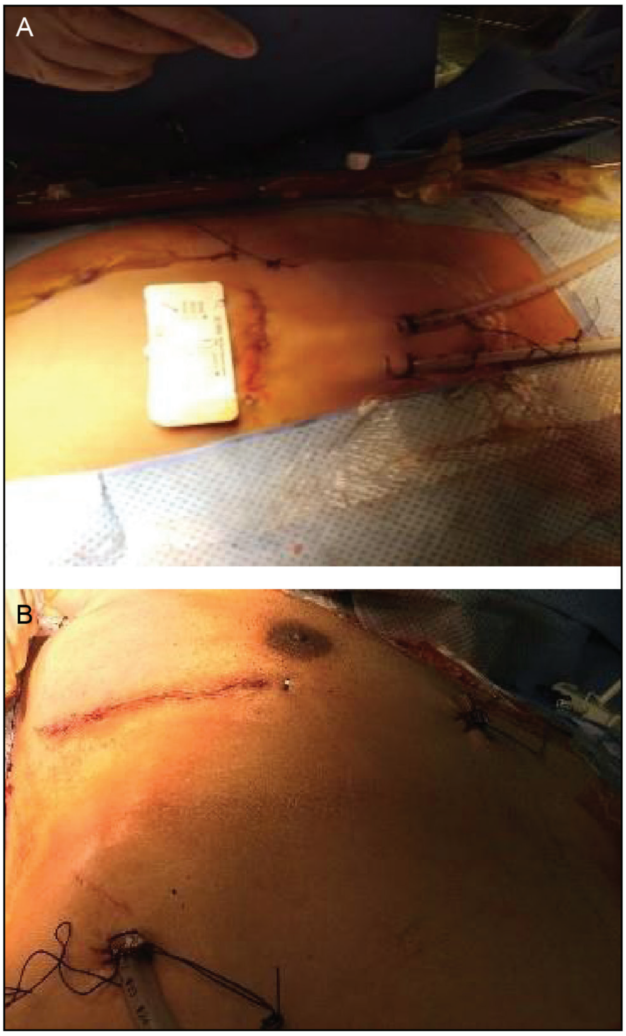
FEV1, forced expiratory volume in 1 s; FVC, forced volume capacity; MIMVS, minimally invasive mitral valve surgery; SMS, standard median sternotomy.
**P* value less than 0.05 statistically significant.

In our study, preoperative PFT was done to all patients before surgery, during the morning in sitting position. The preoperative spirometric study showed insignificant statistical difference between the groups (Table 4). Postoperative spirometric study was performed on all patients on the 7th postoperative day. In group MIMVS, spirometric study revealed that PFT had no significant reduction after surgery denoting better postoperative PFT than the SMS group. There were postoperative significant difference in between both groups regarding FVC and FEV1; however, there was insignificant *P* value of FEV1/FVC between both groups (Table 5).

There was significant *P* value between both groups in mechanical ventilation time (6.4±1.3 MIMVS, 12.4±6.8 SMS), while in ICU stay (2±0.4 MIMVS, 3.5±1.3 SMS) there was no significant difference. Total hospital stay (7.2±1.3 MIMVS, 12±0.5 SMS) revealed significant *P* value (<0.001) between both groups

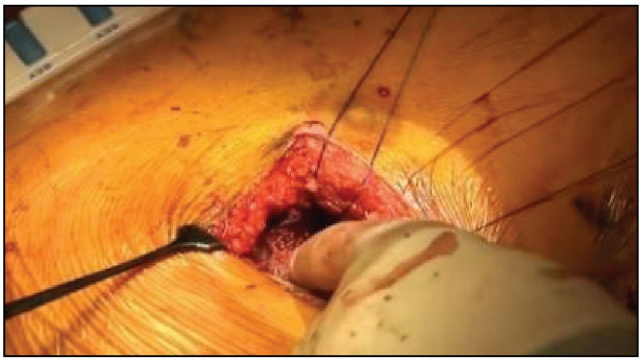
There were no hospital mortality in both groups and all patients were discharged with normal LV function, well-functioning valve, and no pericardial effusion according to postoperative echocardiography. Follow-up postoperatively revealed that all cases were in NYHA I with high significant improvement after surgery, with resumption of normal activity earlier than the SMS group (Figs 5–7).

Figure 5



(a) RMT closure after MIMVS with one drain. (b) RMT closure after MIMVS with two drains. MIMVS, minimally invasive mitral valve surgery; RMT, right minithoracotomy.

Figure 6



Closure of minithoracotomy incision.

Discussion

Some surgeons remained concerned about the risk of groin wound infection, and risk of vascular injury due to peripheral cannulation in MICS [9]. In our study, there was not any wound infection at the cannulation site. There were no recorded wound infection, vascular, or neurological complications because of good preoperative preparation of cases, proper learning curve, clinical history, and computed tomography aortography.

Peripheral cannulation and retrograde arterial perfusion had a risk of aortic retrograde dissection, embolization, and stroke, as well as limb ischemia in cases with severe peripheral vascular disease [10,11]. In our study, with full clinical history, computed tomography aortography, and with TEE guidance all those complications were avoided.

MIMVS through RMT was a safe procedure as the SMS approach in the elderly [12]. In our study, patients were aged 42.6 ± 12.8 years in the MIMVS group; however, it is promising in all age groups when contraindications are absent.

MV repair through RMT provides a durable and safe alternative to SMS with multiple benefits such as improvement of cosmesis, less postoperative pain, minimal blood loss with fewer blood transfusions, low incidence of infection, shorter hospital stay, and rapid return to normal activity [13]. It can be performed with the same incidence of mortality and morbidity to SMS [14]. In our MIMVS group, 12 patients underwent mitral repair (nine with rings and three with mini-bands) with good results with competent repair within the 3-month follow-up.

Some surgeons believed that RMT might be as painful as SMS. There were methods to reduce postoperative pain such as minimization of rib-spreading and intercostal nerve block by bupivacaine injection [15]. In our study, pain visual analog scale at the time of discharge was better in MIMVS than in SMS with significant *P* value (<0.01) because of use of a soft tissue retractor, use of intercostal nerve block, reduce rib spreader, and shorter incision length, avoiding rib fracture, and avoiding cases with chest wall deformity.

Patient selection was the first important step to prevent complications [15]. At the current time, the need of steady learning curve for surgeons and anesthesiologists are required to expand this approach to perform more complex cases, and patients with associated comorbidities; there were also cases with high BMI [16]. Although, obese patients did not have an increase in mortality during open heart surgery, MIMVS in high BMI patients had a lower morbidity and mortality when compared with SMS [4]. Our study showed no significant difference in preoperative comorbid conditions.

Figure 7

(a) Deep sternal wound infection after SMS. (b) Vacuum assisted closure. SMS, standard median sternotomy.

Hybrid percutaneous coronary intervention and MIMVS in patients with prior cardiac surgery is more advantageous than coronary artery bypass grafting and MVS by SMS [16]. However, there were neither redo nor ischemic mitral regurgitation cases in our study.

Many surgeons and their cases agreed that smaller incisions are better because of less pain, early recovery, and more satisfaction with excellent cosmetic results. However, CPB and total operative times are approximately longer (40%) in MIS in some studies. Smaller incisions are more 'patient friendly' for the surgeons [17]. Our cases showed significant difference regarding the length of incision in both techniques.

RMT approach was associated with less new-onset AF, pneumonia, respiratory failure, and acute renal failure, lower drain output, and fewer blood transfusions [3]. Chest drain output was 250 ± 60.6 ml in MIMVS and 550 ± 230 ml in SMS, with a significant *P* value of less than 0.01; besides, blood transfusions were less in the MIMVS group.

MIMVS is safe with low operative mortality. In addition, it is proved to be more cosmetic; it had shorter ventilation time, shorter ICU and hospital stay, and earlier return to daily activities [18]. Preoperative predictors of mortality included advanced age, diabetes mellitus, smoking, dialysis, lung disease, congestive heart failure, and peripheral vascular disease [3]. In our study, there was not any perioperative mortality. Also, there was no difference between both groups regarding ventilation time and ICU stay. There was significant difference in outcome in between the groups as in hospital stay and early recovery.

Elderly patients who underwent MIMVS had a lower morbidity and mortality in comparison to traditional surgery, so this should be recommended in such cases [19]. In our study, both groups included adult age. Also, we excluded ischemic or redo cases, which were common in elder.

MIMVS has mortality rates of 1.2–5.8% in one study. Moreover, it had better recovery and patient satisfaction [6]. In the current era, MIMVS became preferred at many cardiac centers because of less postoperative bleeding and AF. Moreover, the incidence of wound infection and hospital stay decreases. Other benefits were rapid recovery, and better healing [20]. In our centers, patients were asked to perform MICS for cosmesis, less painful, short hospital stay especially with the era of COVID-19.

Surgeons showed a progressive interest toward MICS. It represents a significant change in the techniques that cardiac surgeons will use today. This adds new burden to the surgical team and the anesthesiologists in the techniques and modalities they need training. MIMVS is rapidly growing with excellent results comparable with the SMS approach: it has set equivalent perioperative mortality and less pain, less wound infection, less bleeding, less blood needed, and reexploration for bleeding. It shows better hospital stay and rapid recovery with patient satisfaction.

Conclusion

MIS for the MV showed satisfactory outcome in comparison to the sternotomy approach. The need for rising curve of training for all surgeons is mandatory.

Limitations

Each group has a small number of patients because of the short duration of the study. Two centers' experience with some bias of selection of cases was presented. In spite of being a prospective study, it was not randomized. There is still the need for experience for complex surgeries with the minimally invasive technique.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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