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Initial experience of thoracoscopic video-assisted minimally invasive mitral valve surgery at national heart institute

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Abstract

Background

Advancements in instruments and thoracoscopes and the evolution of cannulation techniques and cannulae types for cardiopulmonary bypass as well as cardiopulmonary bypass machines during the past decade have encouraged many surgeons to adopt minimally invasive mitral valve surgery (MIMVS). Today, MIMVS has become the standard approach for many surgeons and institutions.

Patients and methods

This is a nonrandomized prospective study in which 150 patients of mitral valve pathology scheduled for mitral valve surgery over a period of 3 years from March 2014 to May 2017 at National Heart Institute were allocated to two groups after fulfilling the inclusion criteria. Group 1 underwent conventional mitral valve surgery via median sternotomy and group 2 underwent MIMVS via right lateral minithoracotomy. Data were collected prospectively, and seven parameters were used to compare between study groups, namely, cross-clamp time, total bypass time, dose of inotrope, postoperative ventilation time, ICU stay time, total postoperative length of stay, and return to normal activity.

Results

Demographic criteria of the two cohorts were comparable. Mean bypass time in group 1 was 50.30 ± 7.56 min compared with 67.80 ± 5.85 min in group 2 ($P < 0.001$). Postoperative ventilation time in group 1 was 8.78 ± 2.1 h and postoperative ICU stay was 49.9 ± 11.55 h, whereas in group 2, postoperative ventilation time was 4.78 ± 1.66 h and postoperative ICU stay was 26.1 ± 7.98 h ($P < 0.001$ for both). Total postoperative stay was 6.95 ± 1.26 days in group 1 compared with 4.35 ± 1.55 days in group 2 ($P < 0.001$). Again, return to normal activity was 13.1 ± 4.41 weeks for group 1 compared with 4.45 ± 0.96 weeks in group 2 ($P < 0.001$).

Conclusion

In appropriate patients with mitral valve disease of any cause, a right minithoracotomy approach can be used safely without compromising clinical outcome and with fast return to normal activity.

Keywords: Invasive, minimal, mitral, surgery, vats: video assisted thoracoscopic surgery, svc : superior vena cava, ivc: inferior vena cava

Introduction

Undoubtedly, cardiac surgery is offered to any patient for symptomatic and prognostic reasons. The evolution of minimal invasive cardiac surgery has enabled both cardiac surgeons and hospitals worldwide to achieve their goals of good overall clinical results and short hospital stay, respectively. Moreover, it achieves patient satisfaction and adds enormously to the armamentarium of cardiac surgery field. The overwhelming fact of supervening of minimal invasive cardiac surgery worldwide necessitates that this kind of surgery should be offered to the Egyptian patients. We herein report our experience at National Heart Institute with minimally invasive mitral valve surgery (MIMVS) in comparison with conventional mitral valve surgery over a period of more than 3 years.

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Patients and methods

A total of 150 patients with mitral valve pathology scheduled for mitral valve replacement or repair over a period of 3 years from March 2014 to May 2017 at National Heart Institute were allocated to two groups after fulfilling the inclusion criteria and in nonrandomized fashion and after ethical committee approval at national heart institute. Group 1 underwent conventional mitral valve replacement or repair via median sternotomy, and group 2 underwent thoracoscopic video-assisted mitral valve replacement or repair via right lateral minithoracotomy. The patients' oral consent was taken by explaining the technique to them, especially in the minithoracotomy group.

Inclusion criteria

The following were the inclusion criteria:

(1) Patients with mitral valve pathology plus or minus tricuspid valve pathology and no aortic valve pathology.
(2) Patients with no ischemic heart disease.
(3) Left ventricular function ejection fraction greater than 45% at least.
(4) No chronic renal or liver affection.
(5) No chronic lung disease or respiratory failure.
(6) No re-do patients. Although the lateral thoracotomy incision can be very useful in these cases as proven by Bolotin and his associates [1], it was deemed safer to include only first-do cases to abolish external factors affecting the actual outcome of the cases. However, cases with previous closed mitral valve procedures were included.

Exclusion criteria

The following were the exclusion criteria:

(1) Any patient not meeting the inclusion criteria.
(2) Any patient with impaired right ventricular function.
(3) Any patient with pulmonary artery pressure greater than 60 mmHg.
(4) Any patient with peripheral vascular disease or aortic disease.
(5) Patients with absolute or relative contraindications to the use of transeosophageal echocardiography (TEE).

Absolute contraindications included patients with history of eosophageal spasm, stricture, laceration, perforation, and diverticula (e.g. Zenker's diverticulum).

Relative contradictions were as follows: large diaphragmatic hernia that may significantly hinder TEE imaging because of lack of transducer mucosal approximation, as well as atlantoaxial disease and severe generalized cervical arthritis. TEE, therefore, should never be performed if there is any question about stability of cervical spine. Moreover, patients who received extensive radiation to the mediastinum is another contraindication because of the significant difficulty in probe manipulation within the esophagus. Furthermore, gastrointestinal bleeding and significant dysphagia are also relative contraindications.

Anesthetic technique

Airway management

Although the idea of single lung ventilation was very much applauded in early trials, yet we did not wish to use it, owing to its many drawbacks and complications [2–4]. The patient was intubated with a normal ETT, and during the operation, when the visualization of the field was difficult, momentary cessation of ventilation and lung down was done for no more than 30–60 s.

Transesophageal echo

A TEE probe is inserted into the esophagus to monitor the insertion of the different cannulae during cardiac cannulation, and to monitor cardiac functions and the success of the mitral valve operation on table. Moreover, the TEE is very important to confirm the appropriateness of the patient for a minimally invasive technique before incision. This determination was done before placement of any specialized cardiopulmonary bypass (CPB) cannulae. For example, some surgeons consider the presence of severe mitral annular calcification a contraindication to MIMVS, given the increased degree of operative difficulty.

Patient positioning

In this study, the patient was in a supine position and without the usual shoulder hard pillow under the right scapula, as it might increase the transverse diameter of the thoracic cage making the valve further away. The patient's right arm was deviated slightly from the body to expose the right side of the chest up to the axilla; this permits having enough space for the placement of the working ports [5]. The hung hand was isolated from the metal rod by cloth and loosely wrapped to ensure proper blood supply and correct pulse oximetry reading.

Surgical technique

Group 1

This group underwent the conventional steps of mitral valve replacement via median sternotomy, with cardiopulmonary bypass, and cold blood antegrade cardioplegia with systemic cooling to 32°, classic left atrium incision posterior to Waterston groove, mitral valve explantation, and then pledgeted everting 2/0 ethibond sutures passed in the perimetry of mitral valve ring, followed by the prosthesis sewing ring. Tying the sutures after the prosthesis was seated in place was done, followed by closure of left atrium. If mitral valve repair was contemplated, then assessment of the anatomy was done first, followed by correction of the most obvious pathology like neochordal insertion (4/0 Gortex) or posterior quadrangular resection of prolapsed segment followed by physio II ring insertion using 2/0 ethibond stitches taken in U-shaped fashion around the perimetry of the mitral valve annulus before seating it in place. If tricuspid valve repair was needed, then segmental annuloplasty technique was used by 3/0 pledgeted prolene stitch. Gradual weaning off CPB then followed. Left atrium closure was done followed by removal of cannulae and reversal of heparin by protamine. Hemostasis was done followed by

closure, and then the patient transferred to the surgical ICU as per hospital protocol.

Group 2

Using a surgical marker, we drew lines over the inguinal crease with marking the site of the femoral pulsations, making it in the outer 1/3rd of the planned incision. We also marked the right third, fourth, and fifth spaces. Femoral vessels were exposed before performing chest incision to make sure they are suitable for cannulation using a transverse incision in the inguinal crease, which is better for exposure and cosmesis. Usual tapes or vessel loops were passed around the femoral vessels. Puncturing the vessels at 6–8 cm lower than inguinal ligament line was done to permit a straighter introduction of the venous cannula into the femoral vein. Femoral artery cannulation using the Seldinger technique then followed.

Performance of 4–5 cm right submammary incision at the level of fourth intercostal space in males, and in females, incision in the submammary crease was done, and then dissection below the breast tissues till reaching the fourth space, with extreme caution not to disturb the mammary tissues. Then, the thoracic cavity was entered through the fourth space while temporarily cessation of ventilation to avoid lung injury, and soft tissue retractor was inserted. Any adhesions in the lung or plura were taken down. The right minithoracotomy is made such that the middle part of the incision is positioned in the anterior axillary line. We have started with a more anterior incision at the beginning, for an additional confidence during aortic root cannula placement and removal. Then, with more experience, we gradually switched to a more lateral submammary incision in almost all patients, which gives better visualization of the field and perfect valve exposure.

Steps of the operation

Femoral vein is cannulated using the Seldinger technique under TEE guidance, making sure of the optimum position of the cannula in the SVC. Vacuum-assisted venous drainage is a must to ensure empty heart throughout the operation. Similarly, femoral artery was cannulated. Then, 4–6 cm right submammary incision in the fourth intercostal space was done, followed by entering of the pleural space and visualization of pericardium. Full-dose heparinization was then given guided by ACT more than 400 s or 4 times the control reading before CPB can be safely established. Insertion of thoracoscopic lens (we use 10 mm/30° lens) via port incision was done in the second intercostal space maxillary line. Opening of the pericardium anterior to phrenic nerve was done, and then retracting sutures were used to retract it and hold it in position. Cannulation of aorta for antegrade cardioplegia delivery was done. Cross-clamping of the aorta through a separate 1-cm incision in the right third space anterior axillary line was done. Antegrade cardioplegia was given via direct aortic root cannulation, followed by development of Waterston groove and incising the left atrium just posterior to it. Next, visualization of mitral valve was aided by a special atrial retractor. Especial care was given not to injure the mammary vessels while applying the left atrial retractor rod in a separate incision of third or fourth space parasternal line. Explanation of the diseased mitral valve with preservation of the posterior leaflet if possible. 2/0 ethibond pledgeted everting sutures were taken in the perimetry of mitral valve ring, and then passed through the prosthetic valve.

The valve was then slided down over the sutures to be seated in place before each suture was tied tightly in place using a special knot pusher. The valve was then tested for mobility before left atrium closure using 3/0 prolene suture. If mitral valve repair was contemplated, then assessment of the anatomy was done first, followed by correction of the most obvious pathology like neochordal insertion (4/0 Gortex) or posterior quadrangular resection of prolapsed segment followed by physio II ring insertion using knot pusher. If tricuspid valve repair was needed, one of the three techniques could be used: first, insertion of SVC vent and passing tape around it and withdrawal of venous cannula guided by TEE to IVC; second, head elevation to a high level up to 60 degree and withdraw of venous cannula to IVC, so that blood flows from SVC to IVC passing fossa ovalis, leaving surgical field undisturbed; and third, withdraw venous cannula to IVC guided by TEE and occlude SVC, and then segmental annuloplasty technique was done by 3/0 pledgeted prolene stitch. Closure of the left atrium and deairing by inflation of the lung and filling the heart by partial clamping of the venous cannula. Removal of the clamp was done after TEE confirmation of complete deairing. After the heart was filled and allowed to eject, gradual weaning from bypass was done, and inotropic support was started if needed.

The TEE was used to check both valve position and function and that there was no leakage or restriction of mobility, before removing all cardiac cannulae. Heparin was then reversed by protamine. Hemostasis and wound closure in layers after insertion of two chest tubes. At last, monitored transfer of the patient to the surgical ICU as per hospital protocol was done.

Statistical method

The data were coded and entered using the statistical package IBM SPSS version 23 (IBM, New York, New York, USA).

The data were summarized using descriptive statistics: mean, standard deviation, and median. Statistical differences between groups were tested using χ^2 test for qualitative variables. Statistical differences between groups were tested using independent sample *t*-test for quantitative normally distributed variables. *P* values less than or equal to 0.05 were considered statistically significant.

Results

This is a nonrandomized prospective study started from March 2014 to May 2017, in which 150 patients scheduled for mitral valve surgery underwent either conventional mitral valve replacement via median sternotomy, or thoracoscopic mitral valve surgery at National Heart Institute. A total of 83 patients underwent thoracoscopic minimally invasive

mitral and tricuspid valve surgery (group 2). Mean age in this group was 39.5 ± 3.3 years, and 50 patients were males compared with 33 females. The procedures were one tricuspid valve replacement, eight mitral valve repair, 65 mitral valve replacement only, and nine mitral valve replacement and tricuspid repair. The MIMVS was successfully performed in all cases in the form of 4–5 cm right submammary incision with femoro-femoral cannulation for CPB and long shafted instruments with the aid of thoracoscopic view.

On the contrary, conventional mitral surgery (group 1) consisted of 67 patients, comprising 39 males and 28 females. Mean age was 38.7 ± 1.9 years. The procedures were 53 mitral valve replacement, eight mitral valve replacement and tricuspid valve repair, and six mitral valve repair. The procedures of the study groups are shown in Fig. 1.

As expected, predominant rheumatic pathology was encountered in most MVR cases in both groups. Cases, however, which had a degenerative pathology were subjected to mitral valve repair in either group. Tricuspid valve replacement was performed for infective endocarditis pathology in MIMVS group. The MIMVS procedure was successfully performed in all pathologies encountered. Conversion rate to sternotomy was 0%, and hospital mortality was not encountered (0%).

There were seven parameters measured to compare the two groups: duration of operation (the cross-clamp time and the total by-pass time), dose of inotrope used, postoperative ventilation time in hours, total ICU stay time in hours, the total postoperative length of stay in days, and the return to normal activity in weeks. The definition of normal activity adopted by our department was the ability to resume work, driving his or her car, or doing household activities without feeling musculoskeletal disabling pain or having restriction to do so.

Mean bypass time in group 1 was 50.30 ± 7.56 min and the cross-clamp time was 29.3 ± 3.77 min. In group 2, mean bypass time was 67.80 ± 5.85 min and the cross-clamp time was 53.10 ± 7.14 min, as shown in graphs 1 and 2. So, both the by-pass time and the cross-clamp times in group 1 were significantly shorter than in group 2 ($P < 0.001$) (Figs. 2 and 3). This was expected, understandably, because minimally invasive technique is a fairly new technique, its steps are much more sophisticated and time consuming, and necessary caution is taken by the surgeons during the steps of the operation.

Postoperative ventilation time in group 1 was 8.78 ± 2.1 h and postoperative ICU stay was 49.9 ± 11.55 h, whereas in group 2, postoperative ventilation time was 4.78 ± 1.66 h and postoperative ICU stay was 26.1 ± 7.98 h, as shown in graphs 3 and 4 (Figs. 4 and 5).

The postoperative course of patients in group 2 was significantly shorter than group 1 regarding both ventilation time and postoperative length of stay in the surgical ICU ($P < 0.001$).

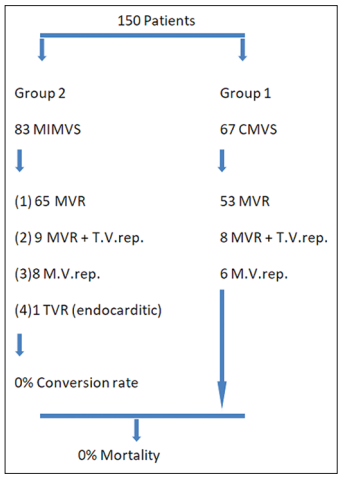

Figure 1: Study group procedures.

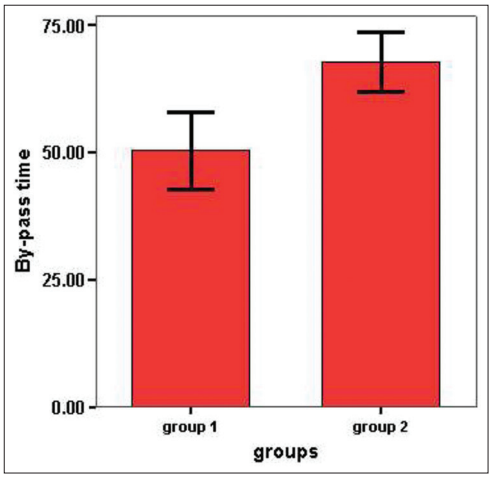

Figure 2: Bypass time.

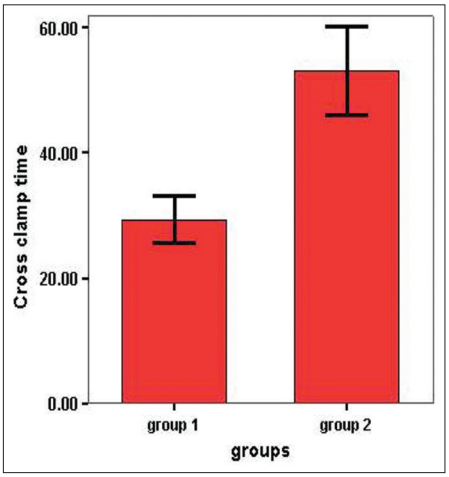

Figure 3: Cross-clamp time.

We had extubated five patients on table intraoperatively from group 2, but we excluded them from the study because we

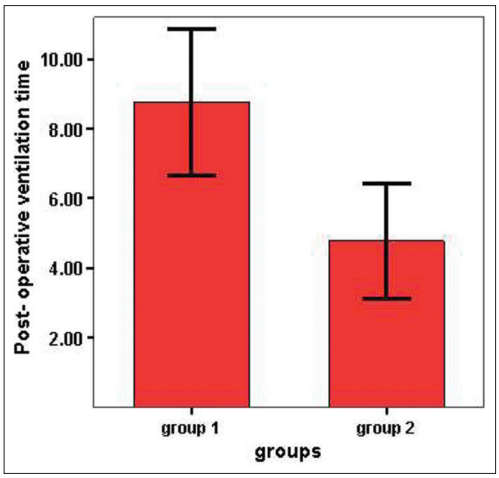

Figure 4: Postoperative ventilation time.

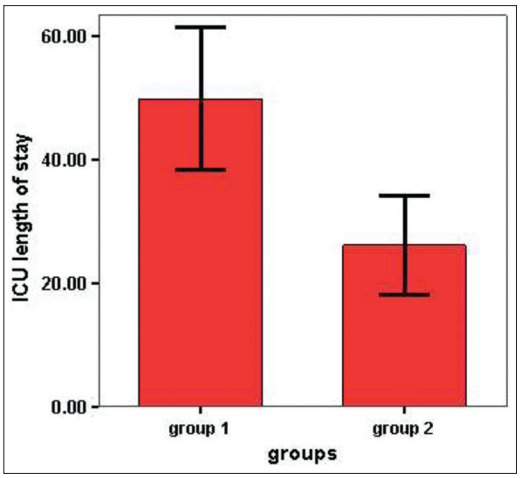

Figure 5: ICU length of stay.

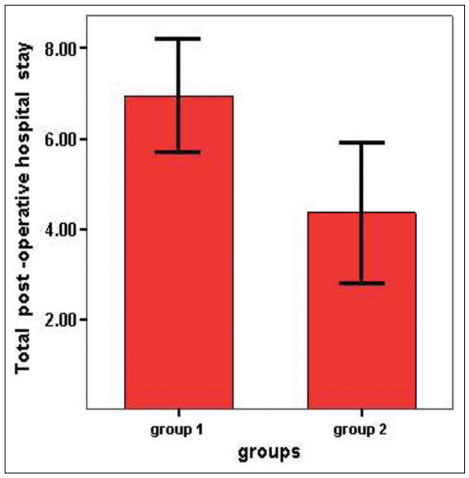

Figure 6: Total postoperative hospital stay.

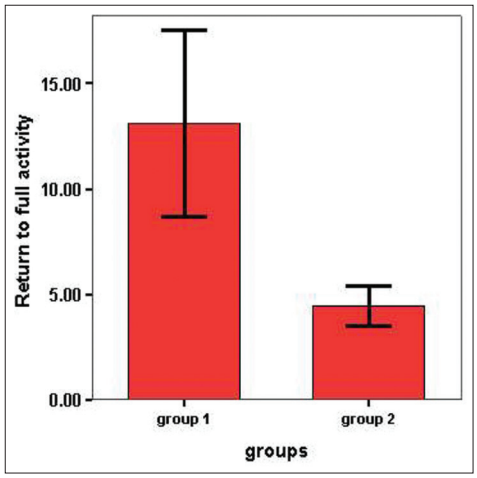

Figure 7: Return to full activity.

found that it provides no extra benefit for the patient, and the ICU team was more apprehensive in dealing with them, as they were not fully awake with slight sluggish responses. Moreover, we needed intercostal local pain management for them for fear of central effect of pain management on respiration.

Regarding total postoperative length of stay in days, depicted by graph 5, it was 6.95 ± 1.26 days in group 1 compared with 4.35 ± 1.55 days in group 2 (Figs. 6 and 7).

Similarly, return to full activity in weeks is portrayed in graph 6, which shows 13.1 ± 4.41 weeks for group 1 compared with 4.45 ± 0.96 weeks in group 2. Again both postoperative length of stay in ward and return to full activity were significantly shorter in group 2 than in group one ($P < 0.001$ and <0.001, respectively). This indicates a shorter time for overall recovery.

For some patients, in both groups, anticoagulation optimization was the only factor that contributed significantly to the length of hospital stay. However, signs of early and better ambulation were noticed in group 2 compared with group 1. Finally, dose of dobutamine in microgram/kg is illustrated in graph 7, which shows 6.79 ± 2.38 μg/kg in group 1 in comparison with 6.86 ± 2.41 μg/kg in group 2 ($P = 0.859$) (nonsignificant) (Fig. 8).

Postoperative morbidity

Right phrenic nerve palsy occurred in one patient from group 2, which recovered after 2 weeks. The right phrenic nerve was anterior than usual to the normally found position, which led to the alteration of site at which the pericardium should be opened. The surgeon, consequently, had loosened the retracting sutures of the lower edge of pericardium as much as he could. Elevated right diaphragmatic copula was noted in x-ray without any other clinical manifestations. Diagnosis was confirmed by paradoxical movement of the diaphragm on fluoroscopy. The patient recovered completely after 2 weeks. Re-exploration for bleeding was done only for one patient in MIMVS group via same thoracotomy incision compared with two patients in conventional group. Superficial femoral wound infection was seen in two female patients in group 2. Superficial chest wound infection was encountered in 1 female patient in group 2 compared with five patients in group 1. Wound complications are shown in Fig. 9. Perioperative summary of the study groups is summarized in Table 1.

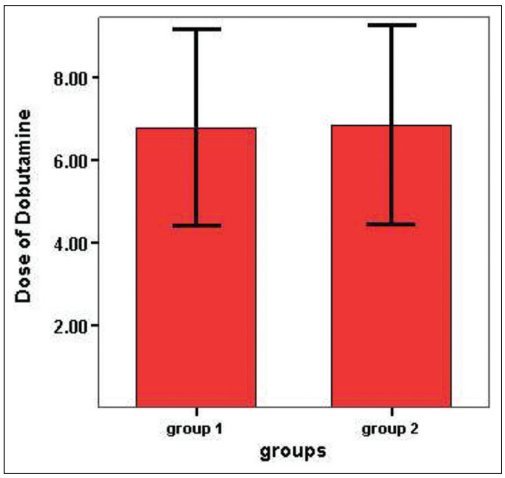

Figure 8: Dose of dobutamine.

Table 1: Perioperative summary of the study groups

	Group 1: CMVS (67 patients)	Group 2: MIMVS (83 patients)	*P*
Males [*n* (%)]	39 (58.2)	50 (60.2)	0.802
Females [*n* (%)]	28 (41.7)	33 (39.7)	
Age (years)	38.7±1.9	39.5±3.3	0.080
CPB time (min)	50.30±7.56	67.80±5.85	<0.001**
Cross-clamp time (min)	29.3±3.77	53.10±7.14	<0.001**
Ventilation time (h)	8.78±2.1	4.78±1.66	<0.001**
ICU stay (h)	49.9±11.55	26.1±7.98	<0.001**
Total postoperative stay (days)	6.95±1.26	4.35±1.55	<0.001**
Return to full activity (weeks)	13.1±0.41	4.45±0.96	<0.001**
Inotrope use (μg/kg)	6.79±2.38	6.86±2.41	0.0.859
Postoperative bleeding [*n* (%)]	2 (2.9)	1 (1.2)	0.439

CMVS, conventional mitral valve surgery; CPB, cardiopulmonary bypass; MIMVS, minimally invasive mitral valve surgery. *Significant. **Highly significant.

Discussion

The results of the National Heart Institute study shows that the MIMVS, when well-planned, can be associated with a short postoperative length of stay and a speedy return of the patient to his full activity.

This anesthetic plan was in concordance with that of Vernick *et al*. [6] and many others, where they also used the TEE for monitoring the insertion of the venous drainage cannula, the deairing of the heart chambers, and assessment of success of the operation.

In our study, owing to the learning curve of this procedure, both by-pass and cross-clamp times were longer than the conventional median sternotomy approach, and this was the same finding that Modi *et al*. [7], Caffarelli and Robbins [8]. In contrary, Sharony *et al*. [9] found by-pass and cross-clamp times comparable in both groups. Obviously, in high-volume centers, operating times approach those achieved with a conventional approach [10].

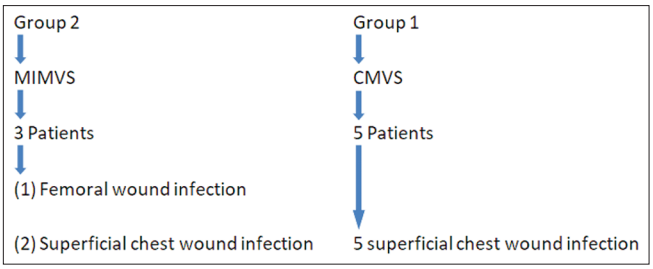

Figure 9: Wound complications of the study groups. CMVS, conventional mitral valve surgery; MIMVS, minimally invasive mitral valve surgery.

We encountered one case of phrenic nerve injury in our study, and luckily enough, it did not cause the patient any harm because he had a good respiratory function preoperatively. This is a well-known possible complication, which can be a major problem for patients with compromised pulmonary function. It could be avoided by opening the pericardium 3–4 cm anterior to it and by avoiding traction on the lower pericardial edge that may cause diaphragmatic paresis owing to stretching of the nerve [11].

Interestingly, we did not have any conversion to sternotomy (0%), which is usually because of bleeding. Again, this is a well-known complication of the MIMVS (0–3.9%) that had been described by some authors [12–14].

In our study, we found ventilation hours and ICU stay to be significantly less in MIMVS group than the conventional group ($P < 0.001$). This is in line with so many authors [15–17] who found the same finding, and this is considered one of the most important privileges of the minimally invasive technique. In contrary to this finding, some authors reported insignificant difference regarding ventilation hours and ICU stay, although their results regarding both were comparable to our study's results, such as Sharony and his coworkers [9].

The postoperative length of stay in our study showed a significant difference between the two groups ($P < 0.001$), where the minimally invasive surgery group stayed an average of 4.35 ± 1.55 days as opposed to 6.95 ± 1.26 days. This was not similar to the result that Svircevic *et al*. [18] and his coworkers had found. In their study, postoperative length of stay showed no significant difference between the two groups.

Logic dictates that the reduction of overall length of stay leads to reduction of the overall costs which make this technique cost-effective. However, this is still debated [15,16]. Another point is that, if these operations can be performed as effectively as the open operation and at the same time significantly reduce the need for posthospital care, it will be an advantage in terms of cost-effectiveness [19].

There was no significant difference between the doses of inotropes (Dobutamine) between the two groups ($P = 0.859$). In fact, this was intentionally done by our team to include only patients with left ventricular ejection fraction equal or more than 45% to avoid the affection of the length of stay by hemodynamic status or lengthy need for inotropic support, and to study the effect of approach of surgery exclusively on patient's course.

In this study, we found return to full activity was significantly shorter in the minimally invasive cohort ($P < 0.001$). This indicates a shorter time for overall recovery, which is concordant with the findings of some authors [15].

Cosmetic results and patient satisfaction are other advantages of the minimally invasive technique owing to the submammary hidden scar as compared to the median sternotomy scar [17,20]. In our experience, and because of the learning curve, we found that the scar becomes smaller with time and evolving experience. This steep learning curve had been described as 'Mount Everest trek'. Now, we believe that we are at the level 2 or 3 of the four levels of MIMVS levels described by Chitwood *et al*. [21], where level 4 refers to completely robotic assisted surgery.

In this study, we also want to stress that the use of thoracoscope and high-definition screen gives a very good view of the operative pathology and helps the surgeon and even the trainee for correct decision making and flawless surgical technique.

So our study proves that the overall performance of MIMVS has better results than the conventional median sternotomy regarding the parameters set to compare between them, which was similar to the conclusion inferred by Goldstone *et al*. [22], who concluded that minimally invasive approach provides at least equivalent results for conventional surgical methods.

So to sum up, there are multiple benefits of MIMVS such as patient satisfaction and shorter time to resumption of normal activities and most importantly, these benefits can be achieved without sacrificing perioperative safety or durability of surgical repair. Despite a steep learning curve that still exists given the high level of case complexity, continued development motivated by increasing patient demand may allow for even further expansion in the use of minimal invasive techniques.

Limitations of the study

For this study to be more accurate, it needs a larger volume of cases and more experience by the surgeons to ensure that the personal experience does not affect the outcomes. Another important point is selection bias, which may affect our results as well as the learning curve. At last, there are several aspects and complications in both groups we did not report that may affect the outcome such as atrial fibrillation and low cardiac output syndrome, because we intended to focus only on the seven given parameters.

Conclusion

Thus, in appropriate patients with isolated mitral valve disease of any cause, a right minithoracotomy approach may be used without compromising clinical outcome, with the added benefits of early extubation, early ambulation, and a fast return to normal activity.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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