Right-sided minithoracotomy versus upper partial ministernotomy in mitral valve replacement

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Background
The mitral valve has been traditionally approached through a median sternotomy. However, significant advances in surgical optics, instrumentation, and perfusion technology have allowed for mitral valve surgery to be performed using progressively smaller incisions including the minithoracotomy.
Objective
To highlight the historical background, surgical anatomy, surgical approaches, and indication of surgery in mitral valve replacement and to compare perioperative morbidity and mortality outcomes in patients undergoing first-time elective mitral valve surgery via upper partial ministernotomy versus right-sided minithoracotomy.
Patients and methods
This study was conducted on 60 patients who had isolated mitral valve disease or mitral valve disease and tricuspid valve disease. All the patients completed the study, and there was no mortality among the patients. The patients were classified into two groups: group I included 30 patients who had mitral valve replacement with or without tricuspid valve repair through right anterior minithoracotomy (4–7 cm via the right fourth intercostal space) and peripheral cannulation via femoral vessels, and group II included 30 patients who had mitral valve replacement with or without tricuspid valve repair through upper partial ministernotomy and central cannulation for standard cardiopulmonary bypass.
Results
There was a significant difference in the intensive care parameters. The mechanical ventilation time was shorter in group I, and the blood loss and the blood transfusion required was lesser in group I. The ICU stay was shorter in group I. There was highly significantly less postoperative pain in group I than in group II. Total hospital stay was less in group I than in group II. Regarding the complications, there was no statistically significant difference between both groups. Data for right anterior minithoracotomy mitral valve surgery demonstrate reduced blood loss, fewer transfusions, less pain, faster recovery, and more cosmetic esthetics compared with upper partial ministernotomy.
Conclusion
We can conclude from previous studies for both groups of patients that minimal invasive approach is feasible for mitral valve surgery without affecting the core of surgery or compromising the surgical target with some advantages and disadvantages and some limitations.

Keywords:
cardiopulmonary bypass, minimal invasive mitral valve replacement, mitral stenosis

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Introduction

The mitral valve is the most complex of the heart's four valves and is the one most commonly associated with disease. There are three main conditions that affect the valve: obstruction (stenosis), leakage (regurgitation), and bulging backward during valve closure (prolapse) [1].

Mitral stenosis is usually caused by rheumatic heart disease. Less common causes include severe calcification of the mitral annulus, infective endocarditis, systemic lupus erythematous, rheumatoid arthritis, and carcinoid heart disease [2].

The most common causes of mitral regurgitation are rheumatic heart disease, infective endocarditis, myxomatous degeneration, chordal rupture, coronary artery disease, and cardiomyopathy [3].

Although the incidence of rheumatic heart disease has steeply declined during the past four decades, it is still a

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major cause of cardiovascular disease in developing countries. It is estimated that 15.6 million people experience rheumatic heart disease worldwide, with ~282 000 new cases and 233 000 related deaths each year [2].

Sir Lauder Brunton was among the first to consider surgical treatment of mitral stenosis in his 'preliminary note' in *The Lancet* in 1902. In 1923, Culter and Levine reported an operation via median sternotomy in which a special curved knife was inserted through the left ventricular apex to cut a stenotic mitral valve [4].

In 1955, surgeons began to think of opening stenosed mitral valves by intracardiac techniques on cardiopulmonary bypass. However, closed heart operations produced such generally good results that the open heart technique did not come into wide use until after 1970 [4].

A number of surgeons realized very early the need for replacing at least some diseased mitral valves. However, it was Starr and Edwards from the University of Oregon Medical Center who, in 1961, first reported successful mitral valve replacement using a mechanical prosthesis [4].

Although the earliest open mitral valve operations were performed through a right thoracotomy, contemporary mitral valve surgery is dominated by a sternotomy approach. Central cannulation and direct aortic cross-clamping enable mitral valve repair or replacement on a still heart with generous exposure and excellent results [5].

However, access to the rather posteriorly located left atrium and to the mitral valve remained difficult in some patients, for example, in patients with an anatomically small left atrium or a very deep chest [6].

Sternal wound complications occur infrequently with an estimated incidence of 1–5%. When they do occur, they are associated with substantial morbidity and mortality and high costs [7].

In an effort to decrease the invasiveness and perioperative disability associated with heart valve surgery, cardiac surgeons have introduced 'less-invasive' mitral valve operations. These operations are characterized by a nonsternotomy (usually a small thoracotomy) incision and some permutation of cannulation, tissue manipulation, aortic occlusion, or visualization techniques [5].

Advances in minimally invasive approaches for cardiac operations have been achieved in the last several years. The development of new techniques and cannula systems has allowed surgeons to place bypass grafts on the heart and perform valvular heart operations without the need for the traditional sternotomy incision [8].

Minimally invasive mitral valve surgery began in 1996 with the development of alternative methods of perfusion and instrumentation that allowed access through small to tiny incisions. That year, Alain Carpentier reported the first minimally invasive mitral repair done using a minithoracotomy and video assistance [5].Among the expected advantages offered by minimally invasive valve surgery are a less traumatic operation with less blood loss, less postoperative pain, and more rapid recovery [9].

Aim

The aim was to highlight the historical background, surgical anatomy, surgical approaches, and indication of surgery in mitral valve replacement and to compare perioperative morbidity and mortality outcomes in patients undergoing first-time elective mitral valve surgery via upper partial ministernotomy versus right-sided minithoracotomy.

Patients and methods

(1) In this prospective comparative study, 60 patients with mitral valve disease requiring mitral valve replacement surgery were selected from the admission clinic at National Heart Institute.
(2) Ethical approval for this study was obtained from the ethics committee for scientific research at Ain Shams University.
(3) A total of 30 patients underwent mitral valve surgery through minimally invasive surgery via right anterolateral minithoracotomy approach (4–7 cm) with femoral artery and vein cannulation. The other 30 patients underwent mitral valve surgery via minimally invasive surgery (upper partial ministernotomy).
(4) Informed consent was obtained from all patients before surgery.
(5) Both groups were operated at Ain Shams University Hospital and National Heart Institute.
(6) The study was performed during the time period from April 2019 till October 2020.

Inclusion criteria were patients with mitral valve disease undergoing valve replacement and patients with mitral valve disease with or without tricuspid disease.

Exclusion criteria were patients with preoperative neurological deficit; patients with other cardiac lesions that need combined surgery like ischemic mitral valve disease, concomitant aortic valve disease, and concomitant congenital heart disease; patients in need of emergency or redo operations; and patients with renal failure.

The patients were divided into two groups: group I (right-sided minithoracotomy group) included 30 patients who underwent open heart mitral valve replacement with or without tricuspid valve repair if needed through right anterior minithoracotomy (4–7 cm via the right fourth intercostal space) and peripheral cannulation via femoral vessels for cardiopulmonary bypass, and group II (upper partial ministernotomy group) included 30 patients who underwent open heart mitral valve replacement with or without tricuspid valve repair if needed via upper partial ministernotomy and central cannulation for cardiopulmonary bypass.

Patients were subjected preoperatively and postoperatively to the following:

(1) Preoperatively:

History taking: a thorough and detailed history was taken with a special concern to the age, sex, and functional class according to New York Heart Association classification.

Clinical examination: a complete clinical general and local cardiological examination was performed with special emphasis on BMI, chest deformity, lower limb edema, and ascites.

Investigations

Laboratory investigations included complete blood count, liver function tests, prothrombin time and concentration, kidney function tests, blood sugar, and virology tests.

ECG

Radiological examination: plain chest radiograph in the posteroanterior view was done in the erect position. Transthoracic echocardiography was done.

The following data were recorded for statistical analysis: demographic data and clinical characteristics, preoperative New York Heart Association classification, And echocardiography finding [ejection fraction (EF), mitral valve lesion, and tricuspid valve disease].

Surgical technique of right-sided minithoracotomy

Patients are positioned supine with the right shoulder elevated 30–50° using a pillow and with the right arm at the patient's side with exposure of mid axillary line on right side.

These patients are intubated with a single-lumen endotracheal tube.

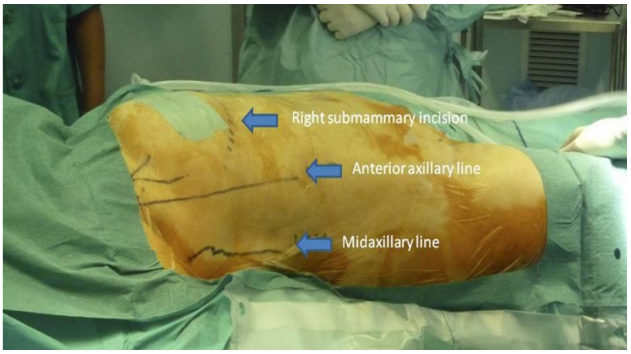
Incision

The incision is placed just below the nipple over the fourth intercostal space (in the infra-mammary crease in most women) 4–7 cm in length. The pectoralis muscles are mobilized for fourth intercostal space thoracic entry. Intercostal ring retractor is used to deflect the soft tissues, while providing minimal rib spreading (Fig. 1).

The pericardium is opened 2 cm ventral to the phrenic nerve under direct vision and carried cephalic to the aortic reflection. The anterior ridge of the pericardium is tacked to incision edges using silk sutures, whereas the posterior edge is distracted posterolaterally using transthoracic sutures. This maneuver rotates the heart counterclockwise, effectively displacing the left atrium laterally and ventrally. This arrangement provides direct-vision exposure and access to the aortic origin, atriocaval junction, and right superior pulmonary vein (Fig. 2).

Three lateral retraction sutures are placed on the posterior pericardial edge. The first is placed over the right superior pulmonary vein and is secured to the lateral corner of the skin incision. The second is placed halfway to the diaphragm and is passed through the chest wall using a 12-G needle, a small hook, and a

Figure 1



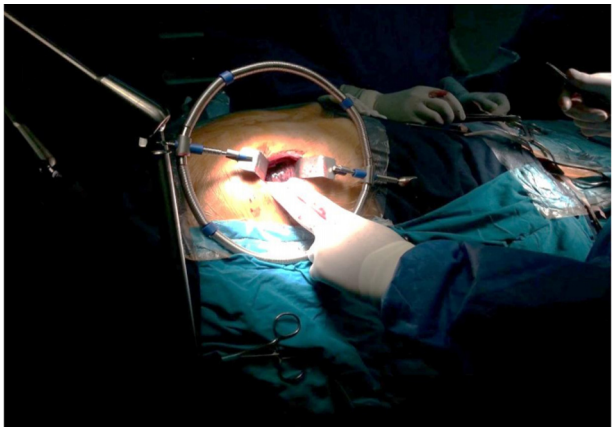
Patient positioning for a right-sided thoracotomy for mitral valve surgery.

small clamp to secure the suture. The third suture is placed at the level of the superior vena cava and is passed through the third intercostal space as laterally as possible. The medial pericardium at the mid-ascending aorta is secured to the posterior sternum to provide aortic exposure to put the aortic clamp and cannulation for cardioplegia.

Cannulation and initiation of cardiopulmonary bypass

To initiate cardiopulmonary bypass, cannulation of the femoral artery and femoral vein should be done before mediastinal dissection. Femoral cannulation is performed through a small 3–4-cm transverse incision in the groin between the pubic tubercle and the anterior superior iliac spine. The femoral artery and femoral vein are exposed and encircled with tapes. Two concentric purse strings are placed in the femoral vein and artery using 5-0 polypropylene suture secured using tourniquets.

Figure 2



Photograph captured showing right minithoracotomy incision with ring retractor placed.

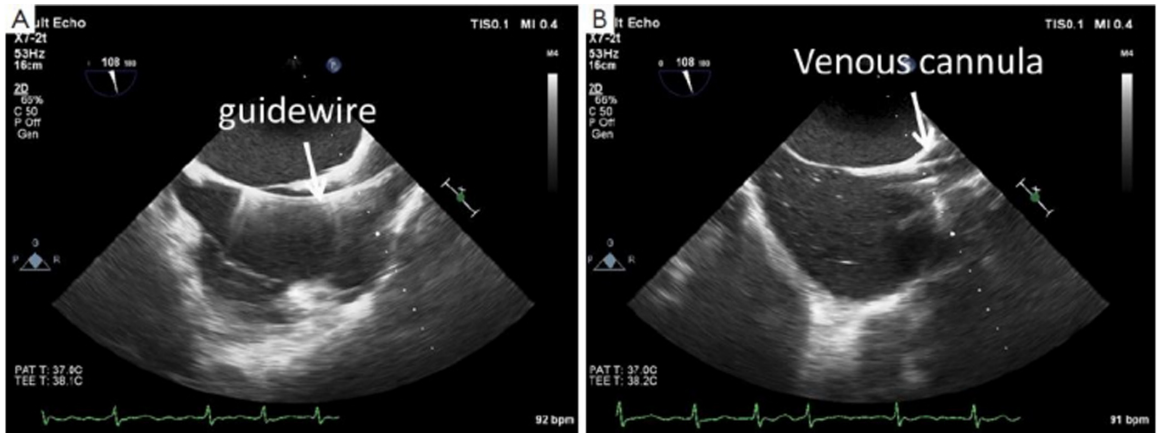
After heparinization, 5-0 polypropylene suture is placed in the common femoral artery; the diameter of the purse strings is less than one-half the diameter of the vessel to avoid vessel stenosis. After controlling the artery proximally and distally, an arteriotomy is made within the purse strings and is dilated to a diameter large enough to pass the arterial cannula. A 21- or 23-Fr arterial cannula is then passed into the femoral artery, placing the cannula tip at least 2 cm into the femoral artery and away from any plaques or bends in the femoral artery. The 5-0 polypropylene tourniquet is then secured, and all tapes on the femoral artery are released, so that the leg will be continuously perfused around the cannula.

A guide wire is then passed up the femoral vein into the superior vena cava using echocardiography, direct palpation, or direct vision. The 22- or 25-Fr femoral venous cannula is then passed over the wire and through the purse strings to place the tip of the cannula 2 cm into the superior vena cava. The 5-0 polypropylene suture tourniquet is then secured, and tapes on the proximal and distal vein are released, allowing continuous venous drainage of the leg and excellent hemostasis. Transesophageal echo guidance is essential to confirm correct luminal passage and destination of the venous cannula, cardiopulmonary bypass is initiated (Fig. 3).

The ascending aorta is occluded with a Chitwood clamp (Scanlan International). This aortic clamp is passed through a separate 1-cm incision downward and lateral to the thoracotomy incision.

The antegrade warm blood cardioplegia is delivered through a standard cardioplegia cannula secured with purse-string sutures in the ascending aorta.

Figure 3



Right minithoracotomy: cannulation. The femoral venous cannula is advanced into the superior vena cava using guide wire technique and echo guidance.

Exposure and valve surgery

With the heart arrested on cardiopulmonary bypass, the left atrium is opened adjacent to the interatrial groove. If needed, the left atriotomy can be extended superiorly behind the superior vena cava and inferiorly behind the inferior vena cava. The view of the left atrium and mitral valve is generally sufficient to perform mitral valve replacement, especially by using three-dimensional atrial retractor with articulated blade (Fig. 4).

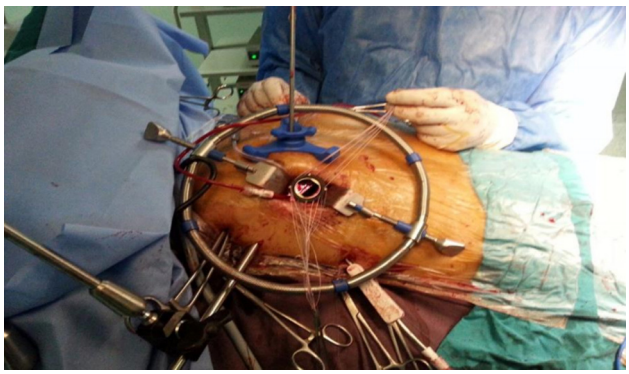
Preservation of papillary muscle–chordal attachments to the annulus was done whenever possible. Everting sutures (atrium to ventricle to sewing ring) were used to ensure adequate function of the prosthetic valve. Teflon pledged sutures were used.

Upon completion of the mitral procedure, the left atrium is closed in a standard fashion with a left ventricular vent passed through the left atrial incision, through the mitral valve, and into the left ventricle.

De-airing of the heart is achieved with the left atrium closed around the left ventricular vent by a tourniquet, and suction is applied to the left ventricular vent with the aorta still clamped. Any residual air on echo can be aspirated through the aortic root vent. Once the heart is well de-aired on echo, the ventricular vent is removed. Closure of the left atriotomy is completed, and removal of cross-clamp is done. The patient is gradually weaned from cardiopulmonary bypass after placement of pacemaker wires on the anterior surface of the heart.

If tricuspid valve repair is needed, the femoral venous cannula is slightly withdrawn to the tip of inferior vena cave, and the superior vena cava and inferior vena cave are snared using nylon tapes. The right atrium is opened, and tricuspid valve repair is done by DeVega suture technique.

Figure 4



Photograph captured during surgery showing minithoracotomy with ring retractor and 3D atrial retractor placed during mechanical valve placement. 3D, three-dimensional.

Closure of the pericardium was done by interrupted sutures over a drain. Another pleural drain is placed in the paravertebral gutter, reaching the apex of the lung. Closure of the ribs is done by interrupted Vicryl sutures. The subcutaneous tissue is closed with absorbable suture.

In the groin region, the arterial and venous purse strings are tied, and the groin incision is closed in a standard fashion. The skin incision and any other port sites are closed with absorbable sutures.

N.B. Intercostal nerve block was performed using Marcaine to reduce postoperative pain.

Surgical technique of upper partial ministernotomy

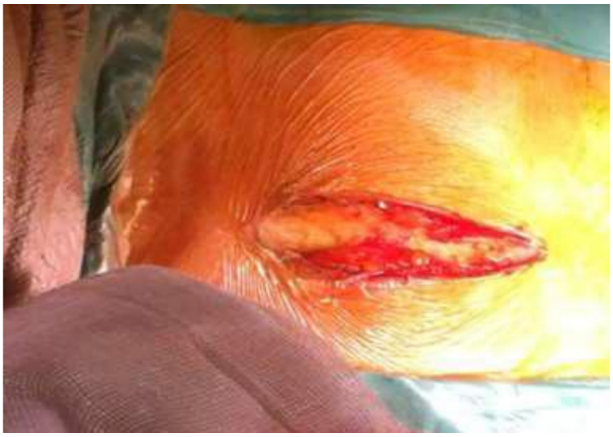
The incision for upper partial sternotomy was 8–10-cm long. It began halfway between the sternal notch and the angle of Louis and ended above the fourth intercostal space. The upper partial sternotomy was performed from sternal notch toward the fourth intercostal space.

It was then extended to the left fourth intercostal space, forming a reverse J-shape sternotomy. The saw was kept till the end of the procedure, for securing the conversion to full sternotomy if needed, at any time (Fig. 5).

The left internal thoracic artery was preserved. A small two-blade retractor was placed, and the upper sternum is opened. The anterior pericardium is opened slightly to the patient right and tacked to the drapes under tension with a heavy stay suture (Fig. 6).

After heparinization, the aorta was cannulated with a 20–22-Fr size soft cannula. A 30-Fr straight cannula is placed through the right atrial appendage into the

Figure 5



Partial upper sternotomy extends from the sternal notch to the left forth-intercostal space.

superior vena cava. An umbilical tape was placed around the superior vena cava, followed by double-way antegrade cardioplegia cannula, which was inserted in the ascending aorta.

Partial cardiopulmonary bypass was established after aortic and superior vena cava cannulation. The right atrium collapses and the inferior vena cava was cannulated posterolaterally in the right atrium with a 32-Fr straight cannula, placed direct into the inferior vena cava, and another umbilical tape was placed around the inferior vena cave and the full bypass was established. The aorta was cross-clamped, and the same cardioplegia solution is administrated. The patient was kept normothermic, and snares around both the inferior and superior vena cavae were tightened.

In mitral valve approach, exposure was done through transseptal incision. The right atrial incision is started in the right atrial appendage and extended caudal toward the inferior vena cava. The atrial septum is opened in the posterior portion of the fossa ovalis, and the incision is cephalad extended with a gentle curve onto the dome of the left atrium.

Two small eyelid retractors are placed in the superior and inferior aspects of the septal incision. This maneuver shows excellent exposure of the mitral valve. Prosthetic mitral valve was placed after removal of the native valve in the standard fashion (Fig. 7).

The incision in the left atrium is closed with a continuous 3-0 polypropylene suture. Before closure of the incision in the interatrial septum, air is evacuated from the left atrium by inflating the lung. De-airing of the left ventricle was facilitated by gentle suction on the aortic root cannula in the aorta before and after removal of aorta cross-clamp.

The incision in the right atrium is closed with a 4-0 prolene, and the pacemaker wires are placed before weaning off bypass. Attempts to defibrillate the heart was done using the use of pediatric paddles after normal cardiac function has returned, the patient is weaned from cardiopulmonary bypass, and the cannulae are removed in the usual fashion. Before off bypass, one or two 38-Fr chest tubes are placed, depending on whether the right pleural space has been opened. The sternum is closed with four or five simple sternal wires; soft tissue and skin are closed in layers (Figs 8 and 9).

Data analysis

Intraoperative assessment included total cardiopulmonary bypass time and cross-clamp time, the need for inotropic support, and ECG changes in the form of ischemia or arrhythmia.

Immediate postoperative assessment included the duration of mechanical ventilation, bleeding and blood transfusion, the duration of ICU stay, and the duration of hospital stay.

Early cardiac and respiratory function assessments: all patients underwent routine preoperative and postoperative transthoracic echocardiography.

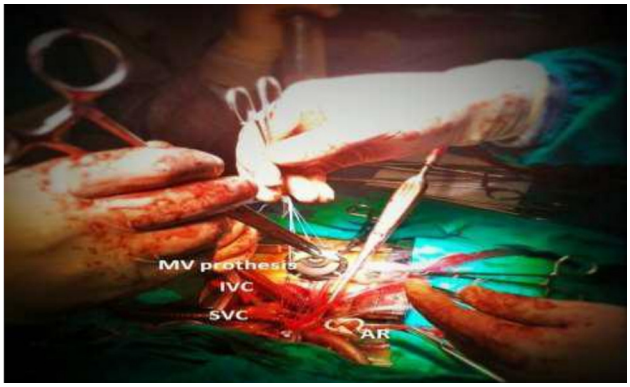
Primary outcomes (most important outcomes to be assessed) included duration of ICU stay, duration of hospital stay, and bleeding and blood transfusion.

Secondary outcome parameters (other outcomes to be assessed) were duration of mechanical ventilation and ECG changes in the form of ischemia or arrhythmia.

Figure 6

A small two-bladed retractor is placed.

Figure 7

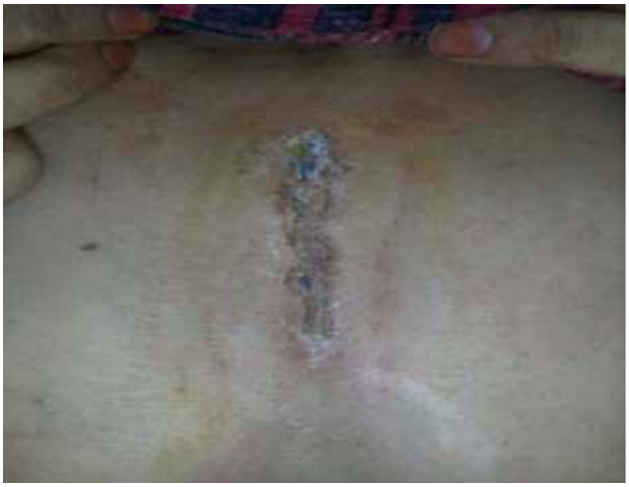


Replacement with prosthetic mitral valve.

Figure 8

The sternum is closed with four sternal wires; soft tissue and skin are closed in layers.

Figure 9



Patient on follow-up.

Data management and analysis: the collected data were revised, coded, tabulated, and introduced to a PC using Statistical package for Social Science ((IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0.; IBM Corp., Armonk, New York, USA). Data were presented, and suitable analysis was done according to the type of data obtained for each parameter.

Descriptive statistics: data were tested for normality with Shapiro–Wilk test and expressed as mean (SD) for parametric numerical data or median (interquartile range) for nonparametric numerical data. Frequency and percentage were used for nonnumerical data.

Analytical statistics: Student *t* test was used to assess the statistical significance of the difference between two study group means. χ^2 test was used to examine the relationship between two qualitative variables. Fisher's exact test was used to examine the relationship between two qualitative variables when the expected count is less than 5 in more than 20% of cells. *P* value as the level of significance was set as follows: *P* value more than 0.05, nonsignificant; *P* value less than 0.05, significant; and *P* value less than 0.01, highly significant.

Results and Discussion

Preoperative data evaluation

In our study, the mean age in group I was 34.6 years, whereas in group II was 38.3 years (Tables 1 and 2). The age groups in our study are younger than the age groups in other studies. Sundermann *et al.* [10] reported a mean age of 57 years, and also in other studies, such as McClure *et al.* [11], Cosgrove and Gillinov [12], where the mean age was above 50 years. The younger mean age in our series may be attributed to earlier and repeated affection by rheumatic fever, which is endemic in most developing countries, including Egypt.

Regarding the sex, in group I, 60% of the patients were males and 40% were females, whereas in group II, 53.3% were males and 46.7% were females. McClure *et al.* [11] reported that regarding sex distribution, more than 60% were males too.

Table 1 Description and comparison between the two study groups regarding personal and medical preoperative characteristics

	Groups			
	Group I Mean/*n*±SD/%	Group II Mean/*n*±SD/%	*P*	Significance
Age	34.60±8.37	38.33±8.88	0.099[a]	NS
Sex				
Male	18±60.0	16±53.3	0.602[b]	NS
Female	12±40.0	14±46.7		
BMI	27.60±2.77	28.43±2.45	0.222[a]	NS
DM				
No	27±90.0	26±86.7	1.0[c]	NS
Yes	3±10.0	4±13.3		
HTN				
No	25±83.3	26±86.7	1.0[c]	NS
Yes	5±16.7	4±13.3		
No	24±80.0	23±76.7	0.754[b]	NS
Yes	6±20.0	7±23.3		
Dyspnea grade				
I–II	11±36.7	14±46.7	0.432[b]	NS
III	13±43.3	14±46.7	0.795[b]	NS
IV	6±20.0	2±6.7	0.125[c]	NS
Diuretics				
No	12±40.0	14±46.7	0.602[b]	NS
Yes	18±60.0	16±53.3		
Anti-arrhythmia				
No	16±53.3	15±50.0	0.796[b]	NS
Yes	14±46.7	15±50.0		
Anti-coagulant				
No	12±40.0	12±40.0	1.0[b]	NS
Yes	18±60.0	18±60.0		

[a]Student *t* test. [b]χ^2 tests. [c]Fisher exact test.

Table 2 Description and comparison between the two study groups and preoperative echo data

	Groups			
	Group I *n*/mean (%/±SD)	Group II *n*/mean (%/±SD)	*P*	Significance
MV				
Stenosis	14 (46.7)	16 (53.3)	0.796[a]	NS
Regurge	7 (23.3)	3 (10.0)	0.166[a]	NS
Double	9 (30.0)	11 (36.7)	0.584[a]	NS
TR				
Mild	21 (70.0)	17 (56.7)	0.284[a]	NS
Moderate	5 (16.7)	3 (10.0)	0.448[a]	NS
Severe	4 (13.3)	10 (33.3)	0.067[a]	NS
EF	63.50 (5.88)	56.83 (4.81)	0.001[b]	HS
	5.18 (0.85)	5.34 (0.83)	0.452[b]	NS
ESD	3.52 (0.53)	3.81 (0.61)	0.051[b]	NS
LAD	5.43 (1.12)	5.58 (0.66)	0.521[b]	NS
PAP	41.43 (12.09)	44.57 (10.09)	0.280[b]	NS

EF, ejection fraction; ESD, end systolic diameter; LAD, left atrial dimension; MV, mitral valve; PAP, pulmonary artery pressure. [a]χ^2 tests. [b]Student *t* test.

The mean BMI in group I was 27.6 and in group II was 28.43. Ghanta *et al.* [13] demonstrated that higher BMI (>30) is associated with increased mortality, major morbidity, and cost for hospital care. As such, BMI should be more strongly considered in risk assessment and resource allocation.

Preoperative echocardiography assessment was done for both groups. In group I, 70% of patients experienced isolated mitral valve disease, whereas 30% had tricuspid valve disease as well. In group II, 56.6% of the patients experienced isolated mitral valve disease, whereas 43.3% had tricuspid valve disease as

well. The EF in group I was 58.70±3.69%, whereas in group II was 54.27±3.53%. The study by McClure *et al.* [11] showed that EF was 60.4±10, which is nearly equal to our study groups.

In our study, the pathology of the mitral valve lesion was pure mitral stenosis in 14 patients in group I and 16 in group II, pure mitral regurgitation was seen in seven patients in group I versus three patients in group II, and mixed pathology was presented in nine patients in group I versus 11 patients in group II. Navia [14] reported that indications for mitral valve surgery were valve insufficiency in 90% of patients, mitral stenosis in 4%, and mixed pathology in 6% of patients. The main etiology was degenerative mitral valves in 82%, and repair was accomplished in 89% of the patients. This difference is attributed to the fact that the main etiology in our study was rheumatic mitral valve and the mainstay of treatment was mitral valve replacement.

Operative procedure data evaluation

In our study, 25 patients in group I underwent mitral valve replacement surgery only versus 19 patients in group II, whereas five (16.7%) patients in group I versus 11 (36.7%) patients in group II underwent combined mitral valve replacement and tricuspid valve repair surgery (Table 3). Umakanthan *et al.* [15] reported that only 10% of patients required combined mitral and tricuspid valve surgery. This difference is attributed to the fact that the main etiology in our study was rheumatic mitral valve with predominant mitral stenosis and the chronicity of the presentation. There was no statistically significant difference in our study groups.

Intraoperative data evaluation

The length of incision was compared in both groups. The mean length in group I was 5.9 cm and in group II was 8.9 cm, with a statistically significant difference (Table 4).

In our study, the group I patients had femoral cannulation of the both femoral artery and vein; the cannulation was through the small 3–4-cm transverse incision in the groin between the pubic tubercle and the anterior superior iliac spine. The femoral cannulation was easy in all patients. We did not need any aortic cannulation.

Several studies reported the use of femoral cannulation for arterial blood flow. Moreover, we believe that the chief disadvantages of right minithoracotomy are the limited field and the relative inaccessibility for cannulation of the aorta [16,17].

Cannulation, cross-clamp time, and total bypass time were compared in the study groups. There was a statistically significant difference between the two

Table 3 Description and comparison between the two study groups regarding type of operation

	Groups [*n* (%)]			
	Group I	Group II	*P*	Significance
Operation				
MVR only	25 (83.3)	19 (63.3)	0.08[a]	NS
MVR and TV repair	5 (16.7)	11 (36.7)		

MVR, mitral valve replacement; TV, tricuspid valve. [a]χ^2 tests.

Table 4 Description and comparison between the two study groups regarding intraoperative data

	Groups			
	Group I Mean/*n*±SD/%	Group II Mean/*n*±SD/%	*P*	Significance
Incision (cm)	5.93±0.78	8.90±0.80	0.001[a]	HS
Operative time	201.33±19.47	177.6±23.12	0.001[a]	HS
CC time	66.90±7.61	46.93±7.54	0.001[a]	HS
CPB time	114.23±10.12	65.00±8.91	0.001[a]	HS
Pre-HCT	45.87±4.01	44.73±5.10	0.342[a]	NS
Post-HCT	33.47±3.54	28.33±4.08	0.001[a]	HS
Drop in HCT	12.40±2.51	16.40±2.87	0.001[a]	HS
Blood transfusion (%)				
No	23±76.7	11±36.7	0.002[b]	HS
Yes	7±23.3	19±63.3		
Inotropes (%)				
No	21±70.0	14±46.7	0.067[b]	NS
Yes	9±30.0	16±53.3		

CPB, cardiopulmonary bypass; HCT, hematocrit. [a]Student *t* test. [b]χ^2 tests.

Table 5 Description and comparison between the two study groups regarding postoperative ICU data

	Groups			
	Group I Mean/*n*±SD/%	Group II Mean/*n*±SD/%	*P*	Significance
Ventilation (h)	3.50±1.28	8.83±2.38	0.001	HS
Drains (ml)	268.33±120.69	568.33±202.35	0.001	HS
ICU stay (days)	1.33±0.48	2.63±0.81	0.001	HS
Blood transfusion (%)				
No	21±70.0	12±40.0	0.02[b]	S
Yes	9±30.0	18±60.0		
Reopening (%)				
No	29±96.7	25±83.3	0.195**	NS
Yes	1±3.3	5±16.7		
CVA (%)				
No	30±100.0	30±100.0	NA	NA

[a]Student *t* test. [b]χ^2 tests. **Chi_square test.

groups regarding the cannulation, cross-clamp time, and the total bypass time. The total bypass time in group I was 114.23 min, whereas in group II was 65.00 min. Cross-clamp time in group I was 66.90 min, whereas in group II was 46.93 min. Total operative time in group I was 201.33 min, whereas in group II was 177.60 min, with a *P* value less than 0.05, denoting statistically significant difference.

This observation is consistent with other studies. Sundermann *et al.* [10] found that cross-clamp time was significantly longer with minimal invasive group versus conventional median sternotomy (94 vs. 74 min). Shinfeld *et al.* [18] reported that in the beginning of the learning curve, cross-clamp time was 25 min longer in the minimal invasive group compared with sternotomy group. However, with experience, cross-clamp time improved in their center but still remained 15% longer in the minimally invasive group.

One of the disadvantages of the right minithoracotomy approach is that it needs a learning curve for the surgeon and team to be able to perform the procedure through a smaller incision in a faster time.

Nine (30%) cases required inotropic support during weaning from cardiopulmonary bypass in group I, whereas in group II, 16 (53.3%) cases required inotropic support during weaning from bypass, with a *P* value more than 0.05, denoting no statistically significant difference.

One of the main advantages of minimally invasive surgery is the decreased amount of intraoperative blood loss and consequently the less need of intraoperative blood transfusion. In our study, there was a statistically significant difference between both groups in hematocrit (HCT) drop, as the HCT drop in group I was 12.4±2.5%, whereas in group II was 16.4 ±2.87%. Moreover, there was a statistically significant difference in need of blood transfusion between both groups: 23% in group I needed blood transfusion in the operative room versus 63% in group II. This observation is consistent with other studies. Menkis *et al.* [19] found that the effect of minimally invasive cardiac surgery on operative blood loss and transfusion need is statistically significant too.

Postoperative data evaluation

ICU data evaluation

In our study, no attempt was done for extubating the patient in the operating theater. All patients in both groups required mechanical ventilation (Table 5). The postoperative mechanical ventilation ranged from 1 to 5 h, with a mean of 3.50 h in group I. In group II, the ventilation time was significantly higher at 8.83 h. This denotes statistically significant difference.

One of the most important advantages of the less invasive technique is the lower incidence of postoperative bleeding and lesser requirement for reexploration. In our study, the mean amount of blood drainage in the first 24 h was 268.33 ml in group I, whereas in group II, the mean amount was 568.33 ml. This difference in both groups is highly statistically significant. Svensson and Cambria [20] reported that less perioperative bleeding and fewer blood transfusions are likely owing to the less extensive mediastinal dissection required for the right anterior minithoracotomy approach. It is possible to stop bleeding from a minithoracotomy incision during entry, whereas sternal bleeding from an upper partial ministernotomy continues throughout the operative procedure. It is suspected that a

Table 6 Description and comparison between the two study groups regarding postoperative ward data

	Groups			
	Group I *n*/mean (%/±SD)	Group II *n*/mean (%/±SD)	*P*	Significance
Infection				
Superficial	1 (3.3)	6 (20.0)	0.103[c]	NS
Deep	0	2 (6.7)	0.49[c]	NS
Rewiring				
No	30 (100.0)	28 (93.3)	0.49[c]	NS
Yes	0	2 (6.7)		
Blood transfusion				
No	27 (90.0)	22 (73.3)	0.095[b]	NS
Yes	3 (10.0)	8 (26.7)		
Total hospital stay (days)	5.67 (0.66)	9.43 (2.16)	0.001[a]	HS
Ward stay (days)	3.30 (0.65)	5.73 (1.62)	0.001[a]	HS
Pain score	4.13 (1.31)	5.43 (1.25)	0.001[a]	HS
EF	56.33 (5.40)	51.97 (3.89)	0.001[a]	HS
Mortality				
No	30 (100.0)	30 (100.0)	NA	NA

[a]Student *t* test. [b]χ^2 tests. [c]Fisher's exact test.

Table 7 Description and comparison between the two study groups regarding postoperative follow-up data

	Groups			
	Group I Mean/*n*±SD/%	Group II Mean/*n*±SD/%	*P*	Significance
EF	58.70±3.69	54.27±3.53	0.001[a]	HS
Dehiscence (%)				
No	30±100.0	29±96.7	1.0[b]	NS
Yes	0±0.0	1±3.3		
Wound (%)				
Closed	30±100.0	29±96.7	1.0[b]	NS
Hypertrophic	0±0.0	1±3.3		
Pain score	1.50±0.51	1.90±0.71	0.015[a]	HS
Need for analgesia (%)				
No	26±86.7	18±60.0	0.02[c]	S
Yes	4±13.3	12±40.0		
Return to work (weeks)	3.93±0.98	8.57±2.06	0.001[a]	HS
Patient satisfaction (%)				
No	4±13.3	30±100.0	0.001[c]	HS
Yes	26±86.7	0±0.0		

[a]Student *t* test. [b]Fisher exact test. [c]χ^2 tests.

sternotomy will continue to bleed into the mediastinum even after it has been reapproximated.

Only one patient in group I required reexploration for bleeding, whereas five patients in group II required reexploration for bleeding. This difference was not statistically significant in both groups. In this study, we cannot comment on the incidence of reopening in both groups owing to limited number of patients, which cannot reflect the significance of reexploration.

As the incidence of bleeding and the amount of blood loss postoperatively is less, the amount of blood transfusion required in group I is less. In our study, the number of patients needed blood transfusion in group I was nine (30%), whereas in group II was 18 (60%). This difference is statistically significant. Owing to the decrease in the demands for blood transfusion, the hazards of blood transfusion are less. Svensson and Cambria [20] reported the same. Other study such as Cheng *et al.* [16] showed no statistically significant difference between both groups in total number of patients required blood transfusion; however, there was a highly statistically significant difference in the number of blood units transfused, with a mean of 3.5±2.9 in group I versus 1.5±1.8 in group II.

The mean stay in the ICU in group I was 1.33 days, whereas in group II, the mean stay was 2.63 days, so the ICU stay was less in group I, with a highly statistically significant difference. Most of the studies performed showed that the mean ICU stay was less in the minimal invasive group. The mean ICU stay reported by Shah *et al.* [21] in the minimally invasive group was 17.1 ±4.2 h, whereas in the sternotomy group it was 21.9 ±3.7 h. This is consistent with the studies by Yung *et al.* [22] (36.3±5 h) and Aybek *et al.* [23] (18 h). Thoracotomy proved to be superior to sternotomy in terms of postoperative ICU stay.

In our study, there was no statistically significant difference between both groups in the analgesic medications needed to maintain patient satisfactory pain control during their ICU stay. This may be attributed to the routine use of intercostal nerve block in the right anterior minithoracotomy. An observational study involving 128 patients of transthoracic clamping reported the use of analgesics and found that there was no difference in the use of morphine in the first three postoperative days between the two groups [22].

Ward data evaluation

The complications reported in both cases were slightly statistically different. This may be owing to the limited number of cases studied (Tables 6 and 7). In group I, one patient had superficial wound infection involving only the skin and responded to frequent dressing and antibiotics, whereas in group II, six patients had superficial wound infection involving only the skin and responded to frequent dressing and antibiotics. Moreover, in our study, we had only two cases in group II with deep sternal infection that required rewiring.

Evaluation of pain by visual analog pain scale was used in the study. In group I, the mean pain score was 4.13. In group II, the mean pain score was 5.43, denoting highly statistically significant change, with low pain sensation in right anterior minithoracotomy. Walther *et al.* [24] compared pain and quality of life after minimally invasive minithoracotomy versus conventional cardiac surgery and reported that mean postoperative pain from 2.7±1.6 in group I to 3.82 ±0.99 in group II. Moreover, they reported that pain levels decreased progressively during the first 7 days postoperatively, and they found that patients having anterolateral minithoracotomy experienced more pain during the first 24 h. From the third postoperative day on ward, patients who underwent anterolateral minithoracotomy experienced less pain. This is an important finding that may be explained by the fact that mobilization of patients with a lateral minithoracotomy is rather painless as compared with upper partial ministernotomy, in which strain caused by mobilization causes bony friction.The same finding was reported by Cooley [25]. He reported a pain score of 4.1 for thoracotomy approach and 4.4 for the sternotomy approach during hospitalization of the patients.

In our study, the mean hospital stay was 5.67 days in group I and 9.43 days in group II. This difference was statistically highly significant, with a *P* value less than 0.01. All the studies reported that hospital stay is significantly less in patients with minithoracotomy than those with sternotomy. Sundermann *et al.* [10] reported a mean hospital stay of 9.4±3.4 days in the sternotomy group and 7.6±3.2 days in the thoracotomy group.

Conclusion

The superiority of right anterior minithoracotomy approach is a shorter ICU stay, total hospital stay, fewer postoperative complications, less postoperative pain, less postoperative blood transfusion, less ventilation time, better cosmetic results, and more patient satisfaction, especially among the females.

On the contrary, upper partial ministernotomy approach is superior in short operation times (cannulation, cross-clamp, and bypass time), as the field is still familiar for the surgeon and shorter in learning curve.

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Conflicts of interest

There are no conflicts of interest.

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