Minimally invasive (limited right anterior thoracotomy) versus conventional approach (median sternotomy) for aortic valve surgery

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Received: 13 July 2022
Revised: 07 August 2022
Accepted: 15 August 2022
Published: 05 April 2023

The Egyptian Journal of Surgery 2023, 41:1251–1267

Background

Minimally invasive aortic valve replacement (MIAVR) has been shown to achieve similar mortality rates to conventional aortic valve replacement, with a smaller incision, lower ventilation time, pain scores, ICU stay, and hospital stay. More efforts should be put in supporting a variety of these strategies.

Objective

The aim was to compare the preoperative and postoperative outcomes of aortic valve replacement through minimal invasive approach (limited right anterior thoracotomy) and the conventional approach (median sternotomy).

Patients and methods

In a multicenter study, 50 consecutive adult patients with severe aortic valve disease scheduled for elective aortic valve replacement in Armed Forces Hospitals from December 2018 to June 2021 were prospectively randomized to undergo either operation through conventional median sternotomy and central cannulation for standard cardiopulmonary bypass (CBP) (MS group I, n=25) or minimally invasive surgery through right anterior small thoracotomy (RAMT group II, n=25). Preoperative clinical evaluation, intraoperative data (site and length of incision and type of cannulation), CBP, and aortic cross-clamp times were evaluated. Postoperative ICU support, including mechanical, chemical (Inotropes), and blood and fluid supports, was evaluated. ICU and hospital stays, ICU mortality, operative cost, and postoperative complications were evaluated.

Results

The incision length was significantly shorter in the RAMT group compared with the conventional group (5.5 vs. 14.5 cm, with P<0.0001). Patients in the RAMT group had longer CBP time (189.1 vs. 166.6 min, P=0.031) and cross-clamping time (141.9 vs. 118.0 min, P=0.003), with nearly equal operative times between the two procedures, and no cases in RAMT were converted to conventional sterornotomy. MIAVR by way of RAMT was associated with significantly lower output of chest drain, lower incidence of usage of blood components, shorter mechanical ventilation time, shorter ICU stay, and shorter hospital stays. RAMT was associated with significantly lower postoperative pain score, with excellent significant scores. However, conventional sternotomy was less costly than RAMT.

Conclusion

MIAVR by right anterior minithoracotomy is a safe and effective surgical method with lower rate of blood loss, as well as a shorter time on mechanical ventilation, time in the critical care unit, and length of hospital stay. More research is needed that includes patients with recorded data after a 1-year follow-up. In addition, in future research, a patient satisfaction survey should be done.

Keywords:

aortic valve replacement, conventional median sternotomy, minimally invasive

Egyptian J Surgery 2023, 41:1251–1267

1110-1121

Introduction

Full median sternotomy (MS) has been well established as a standard approach for all types of open heart surgery for many years. Although well established, the full sternotomy incision has been frequently criticized for its length, postoperative pain, and possible complications like wound infection and instability [1]. Minimally invasive aortic valve replacement (MIAVR) has been shown to achieve similar mortality rates to

 DOI: 10.4103/ejs.ejs_168_22

conventional aortic valve replacement, albeit with more technical demand. MIAVR uses a smaller incision and avoids complete division of the sternum, conferring several benefits such as lower ventilation time, pain scores, intensive care unit stay, and hospital stay. There is also evidence to suggest a lower transfusion requirement during surgery and a reduced volume of blood lost from chest drainage [2].

Aim

The aim of this study was to prospectively compare the preoperative, intraoperative, and postoperative outcomes of aortic valve replacement through minimally invasive approach (right anterior minithoracotomy) and the conventional approach (MS).

Patients and methods

This was a prospective comparative review of 50 patients with severe aortic valve disease scheduled for elective aortic valve replacement. They were divided into two groups: group I consisted of 25 patients who underwent aortic valve replacement through right anterior small thoracotomy, and group II consisted of 25 patients who underwent aortic valve replacement through conventional MS. The study centers were Armed Forces Hospitals from December 2018 to June 2021.

Baseline variables, operative characteristics and outcomes, and major adverse cardiovascular events during the follow-up period were analyzed using our centers' medical records and outpatient surgical and cardiology office visits for three months postoperatively.

Patients with combined cardiac procedure (other valves or coronary lesions), patients with bilateral external iliac or femoral artery stenosis, patients with calcified ascending aorta, patients with complex aortic root surgery (in case of small aortic annulus), and patients with previous sternotomy were excluded.

This study was approved by the local ethical committee of the institute of postgraduate studies, Ain Shams University. In addition, appropriate informed consent from each patient as well as approval from Armed Forces Hospitals was obtained.

In the RAMT group, the intraoperative anesthetic technique was the same as for all patients in the MS group. TOE in minimally invasive cases was a mandatory step manipulated by the anesthetist used for assessment of aortic valve, cardiac function, ventricular filling, intracardiac air, and peripheral cannula insertion. Two defibrillator pads are placed across the chest wall with the right pad placed under the patient's right shoulder and left pad over the anterior left chest wall. A transverse 3–4-cm incision along the inguinal fold over the pulsating femoral artery was made to expose the vessels. Limited dissection and exposure of the anterior aspect of the femoral vessels were recommended. Purse-string sutures with prolene 5/0 taken over the artery and vein were done. When heparin was administered, femoral artery and vein cannulations were performed using a Seldinger technique. Simultaneously, a 5–6-cm skin incision was made beginning at the right sternal border extending to the right anterolateral portion of the chest wall entering into the second or third Intercostal Space (ICS). The RIMA and vein were identified, ligated with one clip proximally and one clip distally. We used a soft tissue retractor and rib retractor to obtain further exposure. We opened the pericardium over the ascending aorta and the pericardium was pulled up, greatly improving aortic exposure.

After the CPB was established, venous drainage was achieved with vacuum assistance. A combined Y-shape cardioplegia/aortic vent catheter was placed into the ascending aorta. The aorta was clamped with a flexible cross-clamp directly through the thoracotomy. Cardioplegia was administered, the patient was cooled, and the temperature was maintained in mild hypothermia at 32°C. We open the aorta in a standard fashion. The surgery proceeded from this point following the typical stages of a conventional valvular procedure. The aortic valve leaflets were resected, then debrided any remaining calcium before placing sutures through the sewing ring and seating the valve in position, and then we tied the sutures beginning with the left coronary annulus, proceeding to the right, and then to the non-coronary annulus.

After finishing the procedure, the aortotomy was closed. A single RV pacing wire was put in place and tunneled out through the anterior chest wall. A skin grounding wire was added. De-airing of the left ventricle and aorta was done before removing the cross-clamp. When the patient was fully rewarmed and cardiac function restored, we weaned the patients from cardiopulmonary bypass (CBP). After 50% of protamine was given, the femoral venous cannula was removed. The remaining protamine was given before removing the arterial cannula. Careful hemostasis was done, and two silicone drains were placed through the ports into the pericardium and right pleural space. Two pericostal sutures were placed for rib re-approximation using vicryl 2 sutures. The pectoralis muscle and the subcutaneous tissue were then closed by continuous absorbable 2/0 sutures, followed by the skin, which was closed by 4/0 subcuticular sutures.

In the MS group, the patient was placed in a supine position, draped, with exposure of the sternum up to the midclavicular line. The incision was begun ~2 cm below the sternal notch and extended ~2 cm beyond the distal tip of the xiphoid process and was extended with electrocautery down to the sternal periosteum. The sternum was then divided in a cephalad-to-caudal direction, and the anesthesiologist was asked to deflate the lungs. A sternal retractor with broad blades was placed and opened slowly. The pericardium was opened; stay sutures by heavy silk usually gave adequate exposure. Aortobicaval cannulation was then performed, and double-way aortic root cannula was inserted for cardioplegia administration and de-airing. After dealing with the aortic valve lesion and weaning from the CBP, decannulation and hemostasis was obtained. Placement of a chest tube was done by inserting one retrosternal tube, and pleural tubes were used if needed. Pacing wires were then inserted. The sternum was then approximated using eight heavy stainless-steel wires. The subcutaneous tissue was then closed followed by the skin.

Preoperative, intraoperative, and postoperative data were recorded for statistical analysis. Preoperative data included age, sex, complaint, full laboratory investigations, ECG findings, echocardiography, pulmonary function tests, plain chest radiography, coronary angiography for patients above 40 years, and duplex for carotid and femoral vessels. Intraoperative data included incision (site and length), type of cannulation either central (aortocaval) or peripheral (femoral artery and vein), total time of bypass, time of cross-clamp, weaning from bypass (smoothly, with chemical support, on IABP, DC shock, on pacemaker, difficult weaning), and total time of the operation. Postoperative follow-up course was divided into two parts: early postoperative while the patients were still in the hospital and three-month follow-up. The early follow-up included the ICU support, either mechanical (IABP and ventilator) or chemical support (Inotropes); blood products; time needed to mobilize the patients; chest drainage; arrhythmias; neurological sequelae; infection; ICU mortality; ICU stay; hospital stay; and patient's complaint (pain, wound complication). The outpatient follow-up in the clinic included breathlessness, patient satisfaction, cosmetic aspect, wound sequelae, the need for readmission, postoperative echocardiography, and cost-effectiveness.

Statistical analysis

Statistical analysis of the data was done using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY) and MedCalc Statistical Software version 20 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2021).

Categorical variables were presented as counts and percentages or ratio, and intergroup differences were compared using Pearson's χ^2-test or Fisher's exact test. Ordinal data were compared using the χ^2-test for trend.

Continuous numerical variables were presented as mean and SD and intergroup differences were compared with the independent samples *t*-test.

Discrete numerical variables were presented as median and range and differences were compared with the Mann–Whitney test.

Time-to-event analysis was done using the Kaplan–Meier method. The log-rank test was used to compare Kaplan–Meier curves.

P values less than 0.05 were considered statistically significant.

Results

According to preoperative data, the mean±SD age of the patients in the RAMT group was 58.6 ± 14.8 years, whereas that in the MS group was 58.4 ± 14.9 years (P=0.947). The majority of the participants were men (n=32; 64%), with 17 experiencing MS and 15 undergoing RAMT, whereas there were eight (36%) female patients in the MS group and 10 in the RAMT group. There were no significant variations in baseline clinical parameters (P>0.05) between the RAMT and MS groups, with male/female ratios of 1.5 and 2.12, respectively (P=0.556) (Table 1).

Mean BMI was nearly similar in RAMT (29.1) and MS (29.8) groups. Regarding sex, the majority were males (n=32; 64%), of whom 17 underwent conventional sternotomy and 15 RAMT. Among female patients (n=18; 36%), eight underwent sternotomy and 10 RAMT. Male/female ratio was 1.5 and 2.12

Table 1 Demographic characteristics of both study groups

Variable	RAMT Group (n=25)	MS Group (n=25)	*P* value
Age (years), mean±SD	58.6 ± 14.8	58.4 ± 14.9	0.947
BMI, mean±SD	29.1 ± 4.1	29.8 ± 5.0	0.609
Sex, female/male	10/15	8/17	0.556

Table 2 Preoperative echocardiographic measures in both study groups

Variable	RAMT Group (*n*=25)		MS Group (*n*=25)		Difference	95% CI	*P* value†
	Mean	SD	Mean	SD			
EF (%)	62.8	11.4	63.4	6.8	0.6	–4.7 to 6.0	0.811
LVEDD (cm)	5.5	0.8	5.9	1.0	0.5	–0.02 to 1.0	0.061
LVESD (cm)	3.6	0.8	3.8	0.8	0.3	–0.2 to 0.7	0.267
Peak PG (mmHg)	91.2	32.8	66.8	28.8	–24.4	–41.9 to –6.9	0.007
Mean PG (mmHg)	53.9	20.1	38.3	17.6	–15.6	–26.3 to –4.9	0.005
AV area (cm^2)	1.0	0.6	1.5	0.9	0.5	0.1 to 0.9	0.026

CI, confidence interval; EF; ejection fraction. †Independent-samples *t*-test.

in RAMT and conventional groups, respectively (*P*=0.556).

The current study found no significant differences between the studied groups in terms of ejection fractions (EF percent) (62.8 ± 11.4 vs. 63.4 ± 6.8%), left ventricel end diastolic diameter (LVEDD) (5.5 ± 0.8 vs. 3.8 ± 0.8 cm), and left ventricle end systolic diameter (LVESD) (3.6 ± 0.8 vs. 3.8 ± 0.8 cm) for RAMT and MS groups, respectively (*P*>0.05). Peak and mean pressure gradients were significantly higher in the RAMT group compared with the conventional group (91.2–53.9 vs. 66.8–38.3 mm Hg) (Table 2).

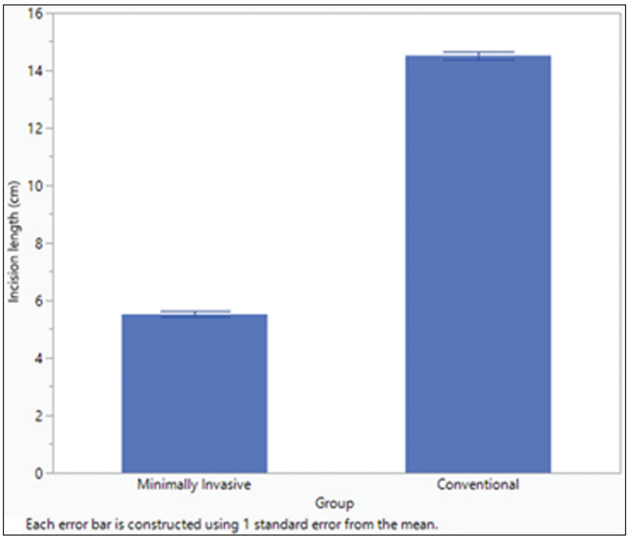
In this study, the incision length in the RAMT group was considerably less than in the traditional group (5.5 ± 0.5 vs. 14.5 ± 0.7 cm, *P*=0.0001) (Fig. 1). Patients in the RAMT group had longer CPB and cross-clamping times (141.9 ± 32.4 vs. 118.0 ± 19.5 min, *P*=0.003) (Fig. 2), with approximately identical operational times (260.8 ± 63.2 vs. 250.2 ± 34.0 min), and no cases in RAMT were converted to conventional sterornotomy (Table 3).

Regarding intraoperative events in the current study groups, our results showed no significant differences between the studied groups regarding difficulties of weaning from CPB, need for inotropic support, DC chock, or need for pacemakers (Table 4). As smaller incisions should theoretically reduce postoperative bleeding and transfusion requirements, minimally invasive AVR by way of RAMT in current study was significantly associated with lower output of chest drain (356.4 ± 98.8 vs. 535.2 ± 212.1 ml) (Fig. 3) and lower incidence of blood transfusion (0–4 vs. 0–10%), with *P* less than 0.01 (Fig. 4, Table 5).

Table 4 shows no significant differences between studied groups regarding difficulties of weaning from CPB, need for pharmacological support, DC chock, or need for pacemakers.

Table 5 shows that minimally invasive AVR by way of RAMT was significantly associated with lower output of chest drain (356.4 ± 98.8 ml vs.

Figure 1



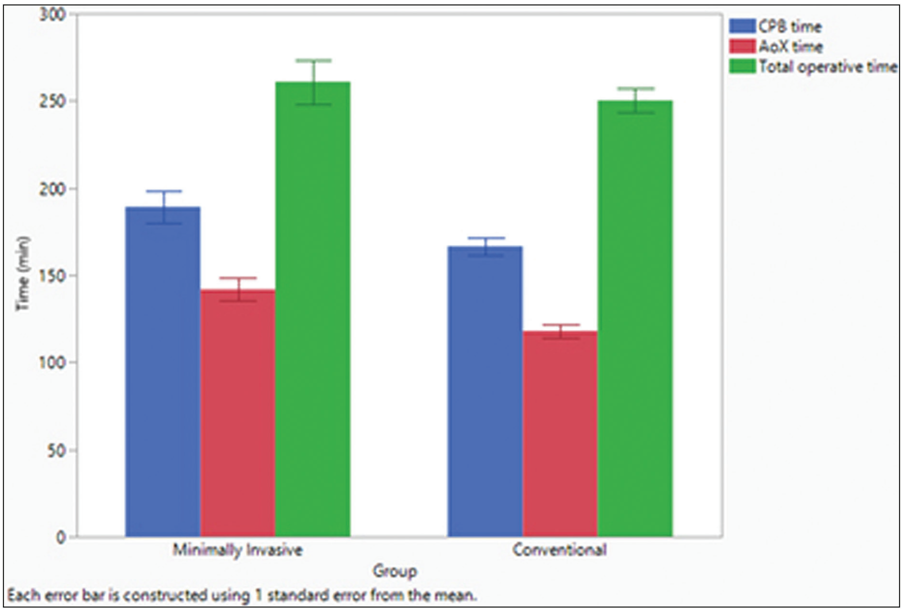
Mean incision length in both groups. Error bars represent standard error of the mean.

535.2 ± 212.1) and lower incidence of usage of blood components (*P*<0.01).

Regarding recovery parameters in the postoperative period in both study groups, minimally invasive AVR by way of RAMT in the current study was significantly associated with shorter mechanical ventilation time (4.8 ± 2.2 h in the RAMT group versus 7 ± 1.9 hours in the MS group) (Fig. 5), shorter time to mobilize the patients (7.1 ± 2.8 h in the RAMT group versus 10.2 ± 3.9 h in the MS group) (Fig. 6), shorter ICU length of stay (39.8 ± 8.3 h in the RAMT group versus 55.7 ± 13.4 h in the MS group) (Fig. 7), and shorter hospital stay (5.4 ± 0.6 days in the RAMT group versus 7.1 ± 0.9 days in the MS group), with *P* less than 0.001 (Fig. 8, Tables 6 and 7).

Regarding the incidence of undesired events after surgery in both study groups, minimally invasive AVR by way of RAMT in the current study was insignificantly associated with lower incidence of postoperative pharmacological support, no heart block, nor neurological deficit compared with the conventional group, with equal incidence of AF (12%) in both groups (Table 8).

Figure 2



Mean cardiopulmonary bypass, aortic cross clamp (AoX), and total operative time in both groups. Error bars represent SEM.

Table 3 Operative details in both study groups

Variable	RAMT Group (*n*=25)		MS Group (*n*=25)		Difference	95% CI	*P* value†
	Mean	SD	Mean	SD			
Incision length (cm)	5.5	0.5	14.5	0.7	9.0	8.6 to 9.4	<0.0001
CPB time (min)	189.1	44.5	166.6	24.2	–22.5	–42.8 to –2.1	0.031
AoX time (min)	141.9	32.4	118.0	19.5	–24.0	–39.2 to –8.8	0.003
Total operative time (min)	260.8	63.2	250.2	34.0	–10.6	–39.5 to 18.3	0.464

CBP, cardiopulmonary bypass; CI, confidence interval. †Independent-samples *t*-test.

Regarding the results of follow-up after hospital discharge in both study groups, the current study showed that patients in RAMT group were more likely to have better New York Heart Association functional class with lower incidence of postoperative wound complication in the RAMT group (one patient of superficial wound infection, one patient with hematoma and one patient with seroma) compared with those in the conventional group (four patients of superficial wound infection, one patient with deep wound infection, and three patients with dehiscence). Our study recorded that the incidence of readmission for wound dehiscence was recorded in one case (4.0%) in the conventional MS group compared with no cases in RAMT (*P*=1.0) (Table 9).

Scar size and postoperative pain are important factors affecting patients' perception and readiness for surgery. In current study, the RAMT incision is more cosmetic and considerably smaller compared with MS (5.5 ± 0.5 vs. 14.5 ± 0.7 cm, respectively, with *P*<0.0001); even some patients used to conceal it with clothes, unlike ministernotomy scar. Minimally invasive AVR by way of RAMT was significantly associated with low postoperative pain score (4.4 ± 1.8 vs. 6.0 ± 1.9) and less analgesic consumption (two vs. four) compared with the MS group with *P* less than 0.01 (Fig. 9, Table 10).

There was no death in the current study participants, neither intraoperatively nor postoperatively (during ICU, hospital stays, and 3 months postoperatively).

As for cosmetic score and overall satisfaction score in both study groups, patients in the RAMT group recorded excellent significant score compared with those in the conventional group (*P*<0.01) (Fig. 10). Moreover, for patient satisfaction (Fig. 11), patients in the RAMT group recorded insignificant higher satisfaction scores compared with those in the conventional group (*P*>0.05) (Table 11).

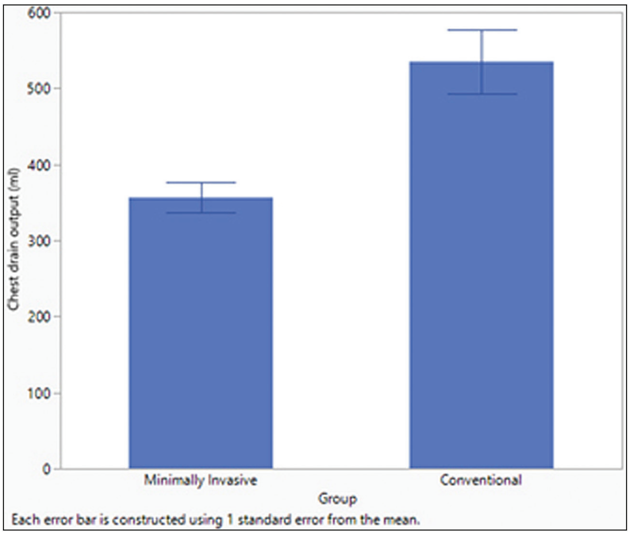
Regarding overall cost of both maneuvers, the current study showed that the conventional MS surgery is significantly less costly than RAMT (88 639.6 ± 9345.4 LE vs. 111 250.4 ± 1626.3 LE, respectively), with *P* less than 0.001 (Table 12).

Table 4 Weaning from CPB in both study groups

Variable	RAMT Group (*n*=25)	MS Group (*n*=25)	*P* value
Weaning from CPB, *n* (%)			
Difficult weaning	1 (4.0)	0	1.000†
Need for pharmacological support	12 (48.0)	13 (52.0)	0.777‡
Need for DC shock	10 (40.0)	11 (44.0)	0.774‡
Need for pacemaker	12 (48.0)	8 (32.0)	0.248‡

CBP, cardiopulmonary bypass. †Independent-samples *t*-test. ‡Mann-Whitney test.

Figure 3



Mean drain output in both groups. Error bars represent SEM.

Discussion

The typical approach for treating aortic valve disease is MS. Despite consistent increases in patient age and overall risk profile over the previous decade, clinical outcomes following AVR have improved significantly [3].

RAMT is a new technique that has been around for only a few years. Owing to the restricted exposure of anatomical features, which makes it more challenging, there were some concerns about the procedure [4].

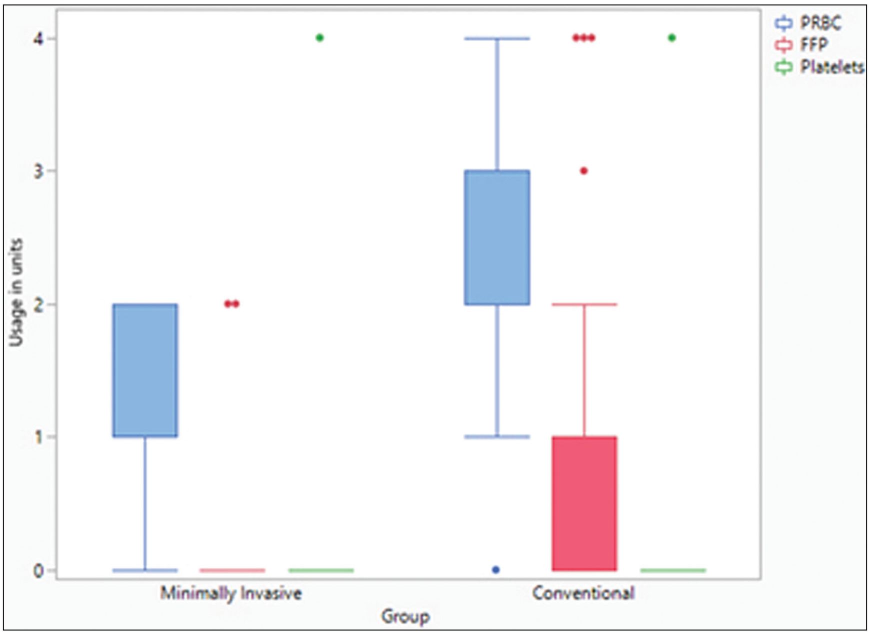
Previous prospective randomized trials have shown the benefits of a minimally invasive technique in terms of reduced bleeding, postsurgical pain and trauma, and shorter hospital and ICU stay lengths, resulting in cost savings and improved cosmetic outcomes [5,6,7], while maintaining the same quality and safety of the standard AVR approach [5,8].

The purpose of our study was to compare the preoperative, intraoperative, and postoperative results of AVR performed using a minimally invasive approach (RAMT) versus a standard method (MS). A total of 50 adult patients with severe aortic valve disease who were scheduled for elective AVR in Armed Forces Hospitals were prospectively randomized to either a MS (MS group, *n*=25) or an RT anterior minithoracotomy surgery (RAMT group, *n*=25) between December 2018 and June 2021.

According to preoperative data, patients in the RAMT group were 58.6 years old, whereas those in the MS group were 58.4 years old (*P*=0.947). The majority of the participants were men (*n*=32; 64%), with 17 experiencing MS and 15 undergoing RAMT. Eight (36%) of the female patients had MS and ten had RAMT. There were no significant variations in baseline clinical parameters (*P*>0.05) between the RAMT and MS groups, with male/female ratios of 1.5 and 2.12, respectively (*P*=0.556). According to Issaka *et al.* [3] the mean age of the patients in the minithoracotomy group was 48.1 (28–69) years and in the MS group was 56.3 (18–84) years, *P*=0.315. *P*=0.485 (minithoracotomy vs. 2 MFS group, sex ratio 3.25). Ferreira and colleagues evaluated the outcomes of aortic valve replacement using a sternotomy with a minimally invasive method using a right anterior minithoracotomy, which is similar to our study. In 22 cases, sternotomy was employed, and in 15 individuals, minimally invasive surgery was used. The sternotomy group was 58.5 ± 16.6 years old, whereas the MIS group was 58.1 ± 17 years old, with no statistical difference (*P*=0.816). Males made up the bulk (*n*=26; 70%), with 17 undergoing sternotomy and nine joining the MIS group. Five female patients (*n*=11; 30%) had a sternotomy and six had the MIS [9].

The current study found no significant differences between RAMT and MS groups in terms of ejection fractions (EF percent) (62.8 ± 11.4 vs. 63.4 ± 6.7%, respectively), LVEDD (5.5 ± 0.8 vs. 3.8 ± 0.8 cm, respectively), and LVESD (3.6 ± 0.8 vs. 3.8 ± 0.8 cm, respectively) (*P*>0.05), whereas peak and mean pressure gradients were significantly higher in the RAMT group compared with the conventional group (91.2 ± 32.8 vs. 66.8 ± 28.8 mm Hg). Issaka *et al.* [3] found that the MIAVR group had a left ventricular ejection fraction (LVEF) of 58.3 percent (35–73) compared with 51.7% (25–78) in the MS group, with *P*=0.359. Mourad and Abd Al Jawad also recently demonstrated that preoperative LV functions were equivalent in both groups, with no statistically significant differences.

Figure 4



Box plot illustrating blood usage in both groups. Box represents the interquartile range (25th–75th percentile). Line inside the box represents the median (50th percentile). Whiskers represent the minimum and maximum values, excluding outliers (rounded markers).

Table 5 Postoperative blood loss and perioperative blood usage in both study groups

Variable	RAMT Group (*n*=25)	MS Group (*n*=25)	*P* value
Chest drain output (ml), mean±SD	356.4 ± 98.8	535.2 ± 212.1	0.0004†
PRBC usage, median (range)	1 (0 to 2)	2 (0 to 4)	0.0004‡
FFP usage, median (range)	0 (0 to 2)	0 (0 to 4)	0.100‡
Platelets usage, median (range)	0 (0 to 4)	0 (0 to 4)	1.000‡
Total usage of blood components, median (range)	1 (0 to 4)	2 (0 to 10)	0.005‡

†Independent-samples *t*-test. ‡Mann-Whitney test.

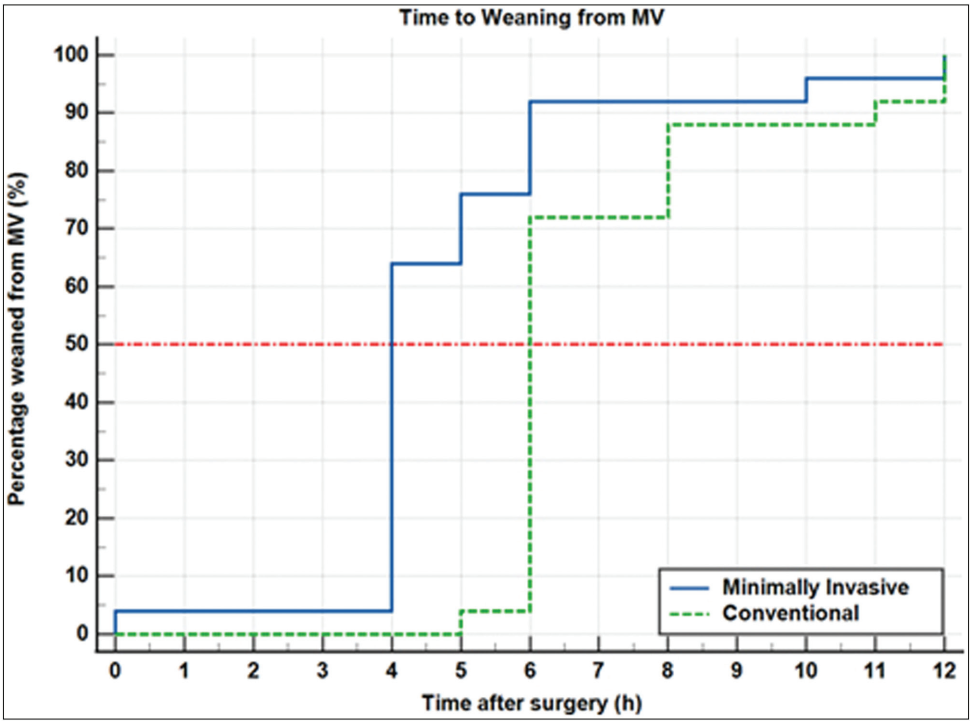
They also showed that postoperative transvalvular mean pressure gradient of implanted valves was significantly higher in the minithoracotomy group (20.24 ± 4.89 mm Hg) compared with the MS group (17.15 ± 5.35 mm Hg), with *P* less than 0.001 [10].

According to a recent scientific statement from the American Heart Association, the term 'minimally invasive' refers to a modest chest wall incision that does not include a typical sternotomy [4]. In this study, the incision length in the RAMT group was considerably less than in the traditional group (5.50.5 vs. 14.50.7 cm, *P*=0.0001). Patients in the RAMT group had longer CPB and cross-clamping times (141.9 ± 32.4 vs. 118.0 ± 19.5 min; *P*=0.003), with approximately identical operational times (260.8 ± 63.2 vs. 250.2 ± 34.0 min).

In agreement with our study, Glauber *et al.* [11] stated that compared with MS, patients in the right thoracotomy group had longer CPB (121.6 ± 45 vs. 107.1 ± 32.3, *P*=0.003) and cross-clamping (86.9 ± 31.8 vs. 72.1 ± 27.2, *P*<0.0001) times .

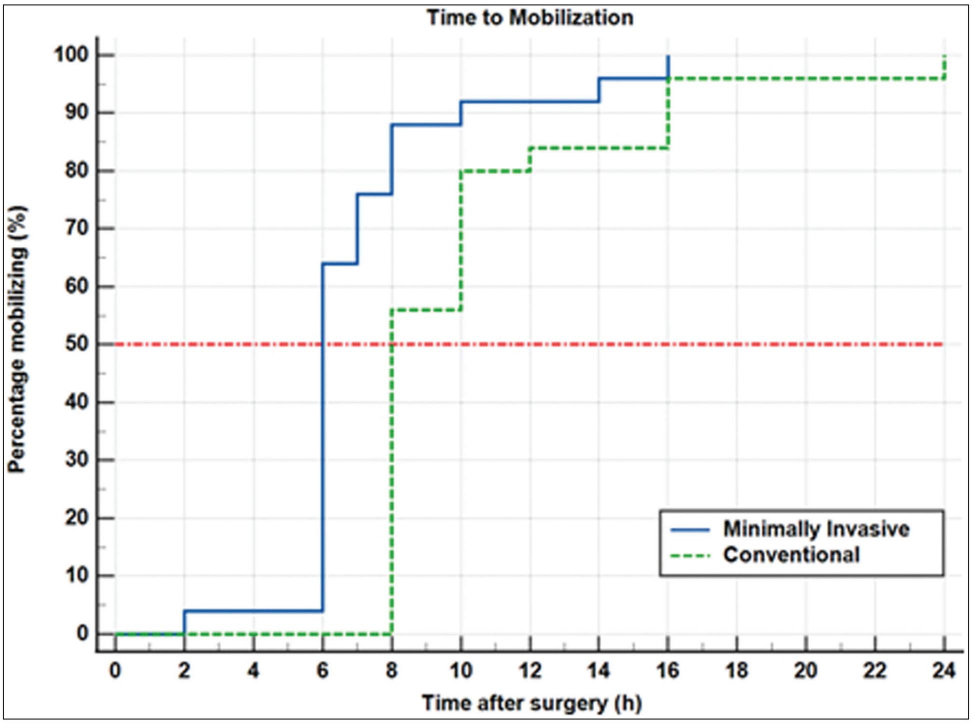
Issaka *et al.* [3] revealed that full sternotomy group had a shorter CPB time [93.25 (58–161) versus 131 (75–215) min, *P*=0.047], but no statistically significant difference regarding aortic cross-clamp time [81 (33–162) versus 58.8 (59–102); *P*=0.158]. Our observation is also consistent with the studies by Ferreira and colleagues and Qu and colleagues: in the first one done by Ferreira and colleagues, the mean CPB time was significantly longer in the MIAVR approach (114.3 ± 23.9 min) than in the sternotomy group (86.7 ± 19.8 min; *P*=0.003). In addition, the mean aortic clamping time was higher for the MIAVR approach (87.4 ± 19.2 min) compared with the sternotomy group (61.4 ± 12.9 min; *P*<0.001). However, in the second study, Qu and colleagues revealed no significant difference in the surgery time between patients undergoing AVR through right anterior minithoracotomy and patients undergoing AVR through MS (233.45 ± 30.94 vs. 236.77 ± 33.96 min, *P*>0:05). The durations of extracorporeal circulation (95.78 ± 16.23 vs. 87.67 ± 15.93 min) and aortic cross-clamping (66.79 ± 15.92 vs. 58.98 ± 15.61 min) in patients undergoing AVR through right anterior

Figure 5



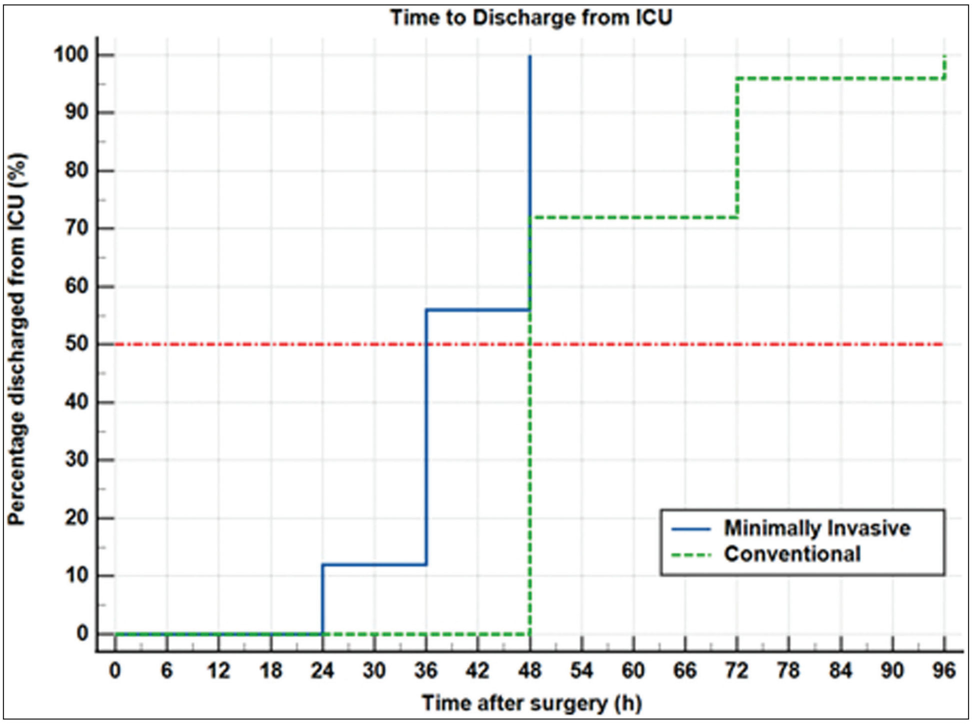
Kaplan–Meier (KM) curves for time to weaning from MV in both groups. Median time to weaning from MV=4 h in the minimally invasive group versus 6 h in the conventional group. Difference between both KM curves is statistically significant (Log rank χ^2=15.869, *df*=1, *P*=0.0001). Incidence rate ratio=5.45, 95% confidence interval=2.37–12.56.

Figure 6



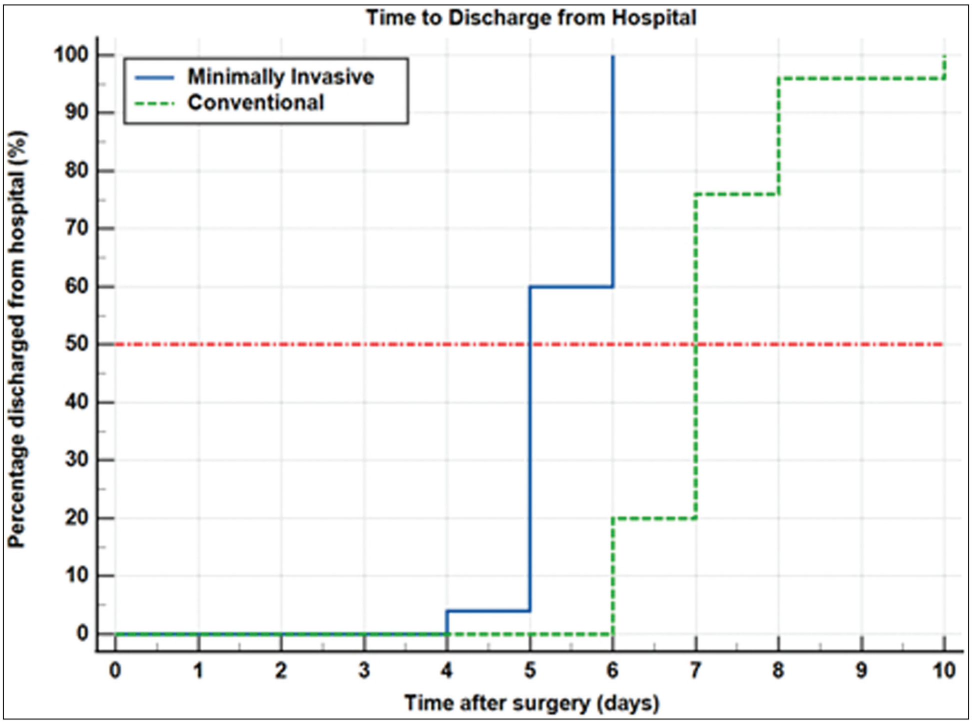
Kaplan–Meier (KM) curves for time to mobilization in both groups. Median time to mobilization=6 h in the minimally invasive group versus 8 h in the conventional group. Difference between both KM curves is statistically significant (Log rank χ^2=17.422, *df*=1, *P*<0.0001). Incidence rate ratio=5.47, 95% confidence interval=2.49–12.46.

Figure 7



Kaplan–Meier (KM) curves for time to ICU discharge in both groups. Median time to ICU discharge=36 h in the minimally invasive group versus 48 h in the conventional group. Difference between both KM curves is statistically significant (Log rank χ^2=22.000, *df*=1, *P*<0.0001). Incidence rate ratio=10.16, 95% confidence interval=3.86–26.76.

Figure 8



Kaplan–Meier (KM) curves for time to hospital discharge in both groups. Median time to hospital discharge=5 days in the minimally invasive group versus 7 days in the conventional group. Difference between both KM curves is statistically significant (Log rank χ^2=38.771, *df*=1, *P*<0.0001). Incidence rate ratio=18.22, 95% confidence interval=7.31–45.44.

Table 6 Recovery parameters in the postoperative period in both study groups

Variable	RAMT Group (*n*=25)		MS Group (*n*=25)		Difference	95% CI	*P* value†
	Mean	SD	Mean	SD			
Duration of MV (h), mean±SD	4.8	2.2	7.0	1.9	2.1	0.9 to 3.3	0.001
Time to mobilization (h), mean±SD	7.1	2.8	10.2	3.9	3.2	1.2 to 5.1	0.002
ICU stay (hours), mean±SD	39.8	8.3	55.7	13.4	15.8	9.5 to 22.2	<0.0001
Hospital stay (days), mean±SD	5.4	0.6	7.1	0.9	1.8	1.3 to 2.2	<0.0001

CI, confidence interval. †Independent-samples *t*-test.

Table 7 Kaplan–Meier time-to-event analysis for relevant end points in both studies

End-point	Minimally Invasive Group (*n*=25)		Conventional Group (*n*=25)		Incidence rate ratio	95% CI	Log-rank test	
	Median	95% CI	Median	95% CI			χ^2 (*df*=1)	*P* value†
Weaning from MV, h	4	4 to 5	6	NC	5.45	2.37 to 12.56	15.869	**0.0001**
Mobilization, h	6	6 to 7	8	8 to 10	5.57	2.49 to 12.46	17.422	**<0.0001**
ICU discharge, h	36	36 to 48	48	NC	10.16	3.86 to 26.76	22.000	**<0.0001**
Hospital discharge, days	5	5 to 6	7	NC	18.22	7.31 to 45.44	38.771	**<0.0001**

95% CI, 95% confidence interval, NC, not calculable. †Log-rank test.

Table 8 Incidence of undesired events after surgery in both study groups

Variable	RAMT Group (*n*=25)	MS Group (*n*=25)	*P* value
Undesired event, *n* (%)			
Need for postoperative pharmacological support	12 (48.0)	13 (52.0)	0.777†
New AF	3 (12.0)	3 (12.0)	1.000‡
New heart block	0	1 (4.0)	1.000‡
New neurological deficit	0	2 (8.0)	0.490‡
Postoperative fever	9 (36.0)	6 (24.0)	0.355†

†Independent-samples *t*-test. ‡Mann-Whitney test.

Table 9 Result of follow-up after hospital discharge in both study groups

Variable	RAMT Group (*n*=25), *n* (%)	MS Group (*n*=25), *n* (%)	*P* value
Breathlessness			
NYHA I	10 (40.0)	5 (20.0)	0.255†
NYHA II	14 (56.0)	20 (80.0)	
NYHA III	1 (4.0)	0	
Wound complications			
Superficial wound Infection	1 (4.0)	4 (16.0)	0.349‡
Deep wound Infection	0	1 (4.0)	1.000‡
Hematoma	1 (4.0)	0	1.000‡
Seroma	1 (4.0)	0	1.000‡
Dehiscence	0	3 (12.0)	0.235‡
Overall incidence of wound complications			
Readmission	0	1 (4.0)	1.000‡

NYHA: New York Heart Association. †Independent-samples *t*-test. ‡Mann-Whitney test.

minithoracotomy were longer than those in patients undergoing AVR through MS ($P<0.05$) [9,12].

Compared with the current study, Del Giglio and colleagues compared right anterior minithoracotomy in 502 patients vs. conventional sternotomy among 678 patients for aortic valve replacement. They revealed that overall procedure duration was significantly higher in right anterior minithoracotomy patients compared with conventional sternotomy patients (195.1 ± 56.8 vs. 167.1 ± 47.2 min, respectively; $P<0.001$). However, CPB time was significantly lower in right anterior minithoracotomy group (61.0 ± 21.0 vs. 65.9 ± 24.7) than in conventional sternotomy group; $P<0.01$). Similarly, aortic cross-clamp times were significantly lower in the right anterior minithoracotomy group compared with the sternotomy group (48.3 ± 16.7 vs. 53.2 ± 19.6 min, respectively; $P<0.01$) [13]. Moreover, Mourad and Abd Al Jawad. showed many interesting differences between both approaches. The MS approach required more time to achieve full cardiopulmonary support

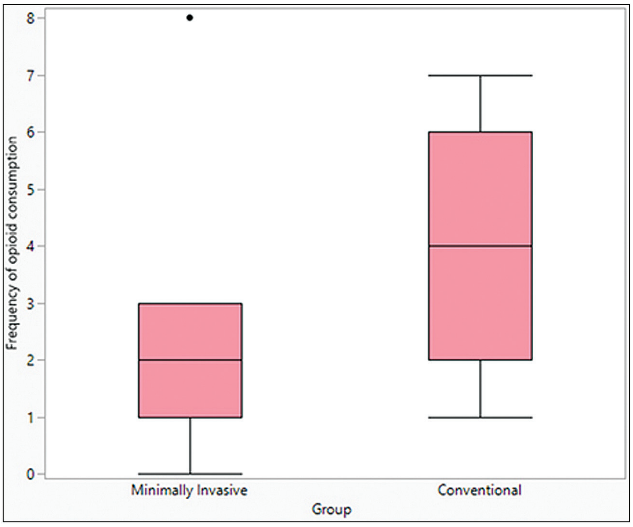
(44.14 ± 2.786 min), whereas the MIAVR approach required significantly lower times in comparison (23.66 ± 6.062 min, P<0.001). On the contrary, the cross-clamp and total bypass times were significantly lower in MS compared with the MIAVR approach (63.61 ± 16.115 vs. 70.75 ± 33.274 min, P=0.028, and 91.90 ± 26.365 vs. 112.24 ± 51.634 min, P<0.001, respectively) [10].

Although there was a slight difference between above studies with our analysis, it is determined by a variety of factors, such as severity of condition on patients, the skill of surgeons, and accident occurrence during operation.

In the current study, no case in RAMT group was converted to conventional MS. In agreement with our study, Issaka *et al.* [3] revealed that in all the patients who underwent AVR, no any patient in the MIAVR required reconversion to full sternotomy.

Compared with current findings, in the study by Glauber *et al.* [11], two patients required intraoperative conversion in the RT group (1.5%): one for a paravalvular leak and one for severe pleural adhesions. In the study by Bowdish *et al.* [14], three conversions from right anterior thoracotomy to sternotomy were performed (1%): two were for coronary injuries requiring coronary artery bypass grafting and the third was to repair a left atrial injury. Moreover, Del Giglio *et al.* [13] recorded that in right anterior minithoracotomy group, intraoperative conversion to full sternotomy was required in two patients owing to paravalvular leakage, which was not safely fixable through the minithoracotomy approach.

Figure 9



Box plot illustrating frequency of opioid consumption in both groups. Box represents the interquartile range (25th–75th percentile). Line inside the box represents the median (50th percentile). Whiskers represent the minimum and maximum values excluding outliers (rounded markers).

Regarding postoperative events in the current study groups, our results showed that there were no significant differences between the studied groups regarding difficulties of weaning from CPB, need for inotropic support, DC chock, or need for pacemakers. Since smaller incisions should theoretically reduce postoperative bleeding and transfusion requirements, minimally invasive AVR by way of RAMT in current study was significantly associated with lower output of chest drain (356.4 ± 98.8 vs. 535.2 ± 212.1 ml) and lower incidence of blood transfusion (0–4 vs. 0–10%), with P<0.01. This is similar to Shehada and colleagues and Johnston and colleagues, who performed a study on 2103 and 2689 patients, respectively, and reported a significantly lower incidence of the need for blood transfusion, as well as respiratory insufficiency in MIVS patients. Similarly, we found that the number of patients who required blood transfusion and the number of units of RBC required for transfusion were significantly reduced in RAMT than in MS [15,16]. These findings were in line with the studies by Glauber *et al.*, Bowdish *et al.*, Ferreira *et al.*, Issaka *et al.*, and Qu *et al.* [8,14,9,3,12].

Glauber and colleagues showed that minimally invasive AVR by way of RT was associated with a lower incidence of blood transfusions in the intensive care unit (18.8 vs. 34.1%, P=0.0006). A permanent pacemaker was implanted in one patient undergoing RT and two patients undergoing conventional sternotomy. In the RT group, two patients were discharged with a mild paravalvular leak; no paravalvular leaks were observed in the conventional sternotomy group [8].

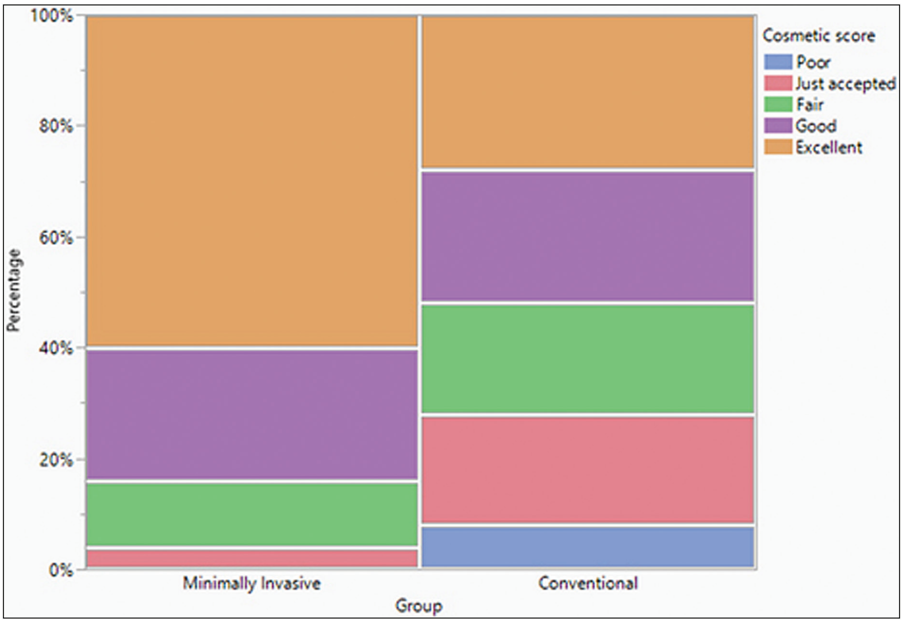
Bowdish *et al.* [14] revealed that intraoperative blood and platelet requirements were lower in the MIAVR group (1.9 ± 2.2 vs. 1.2 ± 1.6 units, P<0.001, for blood, and 1.1 ± 1.4 vs. 0.6 ± 1.0 units, P<0.001, for platelets).

Table 10 Postoperative pain score and analgesic consumption in both study groups

Variable	RAMT Group (n=25)	MS Group (n=25)	P value
Average pain score, mean±SD	4.4 ± 1.8	6.0 ± 1.9	0.003[†]
Frequency of opioid consumption, median (range)	2 (0–8)	4 (1–7)	0.001[‡]

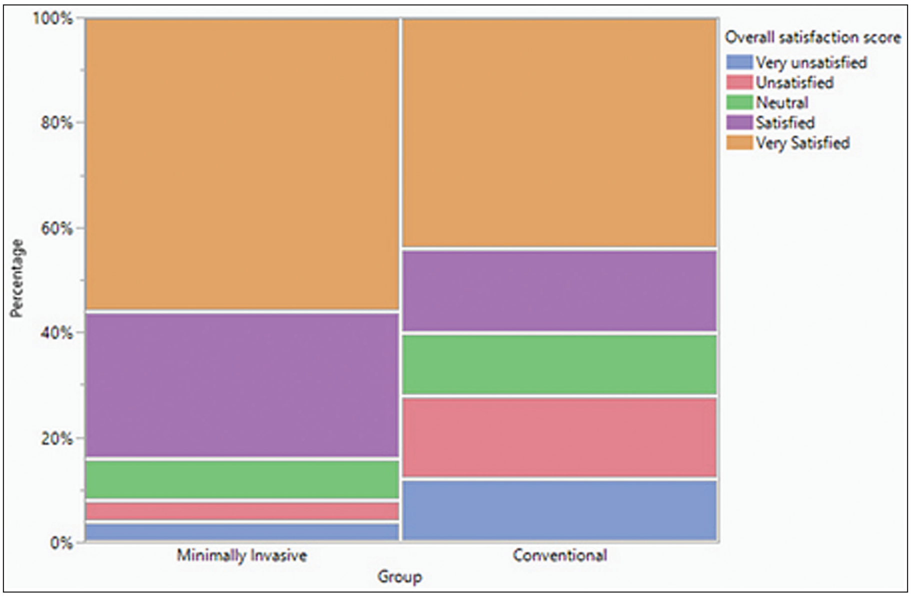
[†]Independent-samples t-test. [‡]Mann-Whitney test.

Figure 10



Cosmetic score in both study groups.

Figure 11



Overall satisfaction score in both study groups.

Ferreira *et al.* [9] found that six (27%) patients of the sternotomy approach group and two (13%) of the MIS approach required transfusion, with no statistical difference between both groups (P=0.49).

Issaka *et al.* [3] during examination of postoperative outcomes revealed that MIAVR patients had likely lower incidence of red blood cell transfusion (16.7 vs. 52.3%), less requirement of inotropic support (16.7 vs. 66.7%, P=0.003), and the chest tube was removed earlier in the MIAVR group (mean 1.53 vs. 2.4 days, P=0.0274).

Qu and colleagues reported that for patients undergoing AVR through right anterior minithoracotomy, the volume of chest drainage within 24 h was 159.85 ± 25.99 ml compared with those undergoing AVR through MS (508.97 ± 102.37 ml) (P<0.05). On the contrary, the incidence rates of blood transfusion within 24 h and postoperative atrial fibrillation were lower in patients undergoing AVR through right anterior minithoracotomy than those in patients undergoing AVR through MS (P<0.05) [12].

Table 11 Cosmetic score and overall satisfaction score in both study groups

Variable	RAMT Group (*n*=25)	MS Group (*n*=25)	*P* value†
Cosmetic score			
Poor	0	2 (8.0)	0.005
Just accepted	1 (4.0)	5 (20.0)	
Fair	3 (12.0)	5 (20.0)	
Good	6 (24.0)	6 (24.0)	
Excellent	15 (60.0)	7 (28.0)	
Overall satisfaction score			
Very unsatisfied	1 (4.0)	3 (12.0)	0.087
Unsatisfied	1 (4.0)	4 (16.0)	
Neutral	2 (8.0)	3 (12.0)	
Satisfied	7 (28.0)	4 (16.0)	
Very satisfied	14 (56.0)	11 (44.0)	

†Independent-samples *t*-test.

Table 12 Overall cost in both study groups

Variable	RAMT Group (*n*=25)	MS Group (*n*=25)	Difference	95 CI	*P* value†
Overall cost (LE), mean±SD	111 250.4 ± 1626.3	88 639.6 ± 9345.4	22 610.9	18 707.1–26 514.6	<0.001

CI, confidence interval. †Independent-samples *t*-test.

Compared with the current study, Bonacchi revealed that respiratory-related complications were higher in the minithoracotomy group, though they showed speedy recovery and weaning off ventilatory support. They showed an increase in pleural drainage, mostly owing to loss of pleural integrity. The results are partially inconsistent with other reports of less ventilation times in ministernotomy [17].

Regarding recovery parameters in the postoperative period in both study groups, minimally invasive AVR by way of RAMT was significantly associated with shorter mechanical ventilation time (4.8 ± 2.2 h in the RAMT group versus 7 ± 1.9 h in the MS group), shorter ICU length of stay (39.8 ± 8.3 h in the RAMT group versus 55.7 ± 13.4 h in the MS group), and shorter hospital stay (5.4 ± 0.6 days in the RAMT group versus 7.1 ± 0.9 days in the MS group), with *P*<0.001.

Murtuza and colleagues, in a meta-analysis of 4667 patients undergoing isolated AVR, demonstrated that those receiving any minimally invasive procedure might benefit in terms of shorter intensive care unit and hospital stay and ventilation time, although the cross-clamp and CBP times were longer [18]. Similarly, Brown and colleagues confirmed these data [19].

Similar to our study, Glauber *et al.* [11] and Merk *et al.* [20] reported in their studies that MIAVR is associated with shorter ventilation time, length of ICU stay, and hospital stay. Issaka *et al.* [3] also recorded that mechanical ventilation time and ICU stay were found to be shorter in the MIAVR group compared with MS group (2.35 (1–12) versus 9.3 (1–48) h, *P*<0.01, for mechanical ventilation time and (2.44 (1–8) versus 4.25 (1–9) days, *P*=0.024, for ICU stay). Moreover, Qu and colleagues revealed that, for patients undergoing AVR through right anterior minithoracotomy, the length of ICU stay, the duration of mechanical ventilation, and the length of hospital stay were 1.78 ± 0.28 days, 15.44 ± 5.74 h, and 8.68 ± 2.74 days, respectively, whereas for patients undergoing AVR through MS, the length of ICU stay, the duration of mechanical ventilation, and the length of hospital stay were 2.14 ± 0.57 days, 18.53 ± 6.72 h and 10.78 ± 2.95 days, respectively [12].

Against our study, Ferreira *et al* [9]. revealed that the mean duration of mechanical ventilation was significantly lower in the sternotomy group (153.9 ± 118.6 min) compared with the MIAVR group (287.3 ± 138.9 min (*P*=0.003).

In contrast to the current findings, studies such Johnston *et al.*, Sansone *et al.*, Gilmanov *et al.*, Young *et al.*, and Del Giglio *et al.* showed similar outcomes between both procedures [21,22,23,13].

For instance, Ariyaratnam *et al.* [24] demonstrated that right anterior minithoracotomy has similar hospital outcomes compared with conventional AVR, and it is quicker and does not confer any significant increase in complications or length of hospital stay.

Regarding the incidence of undesired events after surgery in both study groups, minimally invasive AVR by way of RAMT in the current study was insignificantly associated with lower incidence of postoperative pharmacological support, no heart block, nor neurological deficit compared with the conventional group, with equal incidence of AF (12%) in both groups.

Current findings were similar to Glauber *et al.* [11], where minimally invasive AVR by way of RT was associated with a lower incidence of postoperative AF (18.1 vs. 29.7%; *P*=0.003) compared with MS. Moreover, Ferreira *et al.* [9] recorded six (27%) patients of the sternotomy approach and seven (47%) of MIS approach had AF in the postoperative period, with no statistical difference between the groups (*P*=0.92).

The incidence of AF was similar in Mariscalco *et al.*, 2014, and Miceli *et al.* [25,26], and decreased among the MIAVR approach in the studies by Mihos *et al.* and Lim *et al.* [27,28].

Regarding the results of follow-up after hospital discharge in both study groups, the current study showed that patients in the RAMT group were more likely to have better New York Heart Association functional class with lower incidence of postoperative wound complication in the RAMT group (one patient of superficial wound infection, one patient with hematoma, and one patient with seroma) compared with those in the conventional group (for patients of superficial wound infection, one patient with deep wound infection, and three patients with dehiscence).

The series of Glauber *et al.* [11] reported that the occurrence of stroke, renal failure, reexploration for bleeding, and wound infection was similar in both groups.

Bowdish *et al.* [14] revealed that postoperative wound infections were more common in those patients undergoing a sternotomy (6.6 vs. 1%, *P*=0.004). None of these infections represented cases of mediastinitis; only one in the standard AVR group required surgical reintervention.

Qu and colleagues, in their study among patients undergoing AVR through right anterior minithoracotomy, reported that six cases (13.95%) had ventricular arrhythmia, two cases (4.65%) had low cardiac output syndrome, two cases (4.65%) had infection, two cases (4.65%) had renal failure, one case had pleural effusion (2.33%), two cases had pneumothorax (4.65%), and four cases (9.30%) had atrial fibrillation. Among patients undergoing AVR through MS, seven cases (16.29%) with ventricular arrhythmia, three cases (6.98%) with low cardiac output syndrome, two cases (4.65%) with infection, three cases (6.98%) with renal failure, one case with pleural effusion (2.33%), three cases with pneumothorax (6.98%), and 13 cases (30.23%) with atrial fibrillation were observed. Regarding the incidence rates of ventricular arrhythmia, low cardiac output syndrome, infection, renal failure, pleural effusion, and pneumothorax, no remarkable differences were found between these two groups of patients (*P*>0:05) [12].

The current study recorded that the incidence of readmission for wound dehiscence was recorded in one case (4.0%) in the conventional MS group compared with no cases in RAMT (*P*=1.0). Glauber and colleagues recorded that 4.3% of patients in the conventional sternotomy group were readmitted for bleeding and 6.5% in the RT group (*P*=0.6). In the RT group, the causes of reexploration for bleeding were medical related to coagulopathy in five patients and surgical in four patients related to either some vessels in the subcostal soft tissue (*n*=2) or the suture lines of the aortotomy (*n*=2). In the conventional sternotomy group, four patients required reexploration for bleeding for coagulopathy and two patients for sternal suture sites [11]. Del Giglio *et al.* [13] found one patient in the conventional AVR group had to be reoperated owing to early endocarditis.

Scar size and postoperative pain are important factors affecting patient's perception and readiness for surgery. In the current study, the RAMT incision was more cosmetic and considerably smaller compared with MS (5.5 ± 0.5 vs. 14.5 ± 0.7 cm, respectively, with *P*<0.0001); even some patients used to conceal it with clothes, unlike ministernotomy scar. Minimally invasive AVR by way of RAMT was significantly associated with low postoperative pain score (4.4 ± 1.8 vs. 6.0 ± 1.9) and less analgesic consumption (2 vs. to 4) compared with the MS group, with *P* less than 0.01.

Recently, Mourad and Abd Al Jawad found that regarding patient satisfaction, in terms of the length of incision and postoperative pain, the minithoracotomy group had significantly shorter lengths of wounds (5.1 ± 0.6 vs. 8.48 ± 0.344 cm, *P*<0.001. However, this is quite the opposite when it comes to postoperative pain score either in the ICU, at hospital discharge, or after 30 days at the outpatient clinic, where the MS had significantly lower scores compared with MT (4.46 ± 1.23 vs. 5.23 ± 1.12, *P*<0.001, 1.6 ± 0.84 vs. 1.83 ± 0.72, *P*=0.019, and 1.28 ± 0.67 vs. 1.47 ± 0.53, *P*=0.012, respectively) [10].

There was no death in the current study participants, neither intraoperatively nor postoperatively (during ICU or hospital stays). Our observations are consistent with Glauber *et al.*, Del Giglio *et al.*, and Issaka *et al.*, who showed no difference between MIAVS and MS in term of perioperative morbidity and mortality [11,13,3]. Merk *et al.* [20] reported the same results but with a higher long-term survival in MIAVS than the MS group. However, as our series, RAMT was associated with improved early postoperative outcomes compared with the MS procedure.

Compared with the current findings, Bowdish and colleagues recorded that in the SAVR group, three patients died of fatal arrhythmias and two died of multisystem organ failure (secondary to liver failure/sepsis in one, and renal failure/endocarditis in the other). In the MIAVR group, all deaths were due to multisystem organ failure from surgical complications (postoperative dissection, coronary obstruction, and left ventricular outflow tract obstruction) [14].

A comprehensive systematic literature research by Mohamed and colleagues was performed for studies comparing MIAVR and MS up to February 2021. A total of 10,194 patients from 30 studies (six RCTs and 24 PSM studies) were analyzed. Early mortality differed significantly between the groups (MIVS 1.2 vs. MS 1.9%; P=0.005) [29].

Furthermore, Salmasi *et al.* [2], in their systematic review compared the outcomes between two minimally invasive approaches for AVR, that is, ministernotomy (MS) and right anterior thoracotomy (RAT), in the period 1990–2019 in nine observational studies (n=2926 patients). They revealed no difference in operative mortality between MS and RAT.

Hospital mortality was assessed in 12 studies, and in 10 of them, there were no differences between the two approaches [21,22,25,30,26,31,28]. In two related studies of Johnston *et al.* and Paredes *et al.*, there was a reduction in mortality in the MIAVR approach [16,32]. In this study, we reported no deaths during the hospital stay.

As for cosmetic score and overall satisfaction score in both study groups, patients in the RAMT group recorded excellent significant score compared with those in the conventional group (P<0.01). Moreover, for patient satisfaction, patients in the RAMT group recorded insignificant higher satisfaction score compared with those in the conventional group (P>0.05). In agreement with our study, Qu and colleagues retrospectively analyzed 43 cases undergoing AVR through MS and 43 cases undergoing AVR through right anterior minithoracotomy, in a bid to find an alternative, less-invasive approach to MS during AVR surgeries. The total curative rate was 88.37% for patients with low LVEF undergoing AVR through right anterior minithoracotomy, including 16 cases (37.21%) defined as excellent, 22 cases (51.16%) defined as good, and 5 cases (11.63%) defined as poor. The total curative rate of patients undergoing AVR through MS was 86.05%, involving 14 cases (32.56%) defined as excellent, 23 cases (53.49%) defined as good, and six cases (13.95%) defined as poor. There was no significant difference in the total curative rate between the two groups (χ^2=1:167, P=0:093) [12].

Regarding overall cost of both maneuvers, the current study showed that the conventional MS surgery is significantly less costly than RAMT (88,639.6 ± 9,345.4 LE vs. 111,250.4 ± 1,626.3 LE, respectively) P<0.001. This is in line with Ferreira *et al.* [9], where the cost-effectiveness plane indicates that conventional surgery is less costly and more beneficial than minimally invasive surgery; contact with health care professionals was greater in the mini group, although there was no clear pattern of use.

In terms of cost, we believe that although the operative procedure would be more expensive in the minimal invasive group than in the conventional group, the overall cost, which includes the ICU, hospital stays, medications, blood product transfusions, and the consequences of readmission in the event of wound infection, would be very reasonable, if not even less so. Instruments and consumables are the reasons behind the high cost of minimally invasive procedures. The DC pads, soft tissue retractors, femoral arterial and venous cannulae, and vacuum oxygenator are the main differences between the two techniques where it is a redo case. Single lung ventilation using a brachial blocker or a double-lumen endotracheal tube is also considered when doing minimally invasive, plus inserting transverse pacing wires as the RV would not be accessible owing to adhesions.

Conclusion

MIAVR is a safe and successful surgical procedure that avoids sternotomy and rib fracture, resulting in improved cosmetic and functional outcomes as well as patient satisfaction. We observed no significant differences in death or morbidity in our research. MIAVR was connected to a decreased rate of blood loss, as well as less time on mechanical ventilation, time in the critical care unit, and length of hospital stay, when compared with those who received a full sternotomy.

Our research shows that the advantages of a right anterior minithoracotomy approach go far beyond a superior cosmetic outcome. It shows that this surgery may be done safely and with improved early postoperative outcomes, such as a speedy recovery, with very comparable risk to the conventional MS method.

Summary

MIAVR has been shown to have similar mortality rates to standard aortic valve replacement, despite higher technical requirements. MIAVR features a smaller incision and does not require a thorough division of the sternum, which has a number of benefits, including shorter ventilation times, lower pain scores, shorter ICU stays, and shorter hospital stays. There are also signs that there will be fewer transfusions required during surgery and that the amount of blood lost during chest drainage would be reduced.

However, because of the restricted area available, minimally invasive techniques take longer to perform, even though minimally invasive AVR has been found to reduce aortic cross-clamping and CPB times.

As a result, more efforts should be made to assist the proliferation of these tactics. The purpose of this study was to compare the preoperative and postoperative outcomes of aortic valve replacement using a less-invasive method (limited right anterior thoracotomy) to a traditional strategy (MS).

From December 2018 to June 2021, 50 adult patients with severe aortic valve disease who were scheduled for elective aortic valve replacement in Armed Forces Hospitals were prospectively randomized to either minimally invasive surgery through right anterior small thoracotomy (RAMT group I, n=25) or traditional MS and central cannulation for standard CBP (MS group II, n=25).

CBP and aortic-clamp times were measured preoperatively, intraoperatively (location and length of incision; method of cannulation), and postoperatively. Mechanical, pharmacological (Inotropes), and blood and fluids assistance in the ICU after surgery were measured as well. The length of time spent in the intensive care unit and in the hospital, as well as ICU mortality, operative costs, and postoperative problems were all assessed.

Statistical analysis of current findings revealed the following:

(1) Patients in the RAMT group were 58.6 years old, whereas those in the conventional group were 58.4 years old.
(2) The mean BMI in the RAMT (29.1) and MS (29.8) groups was substantially identical.
(3) There were no significant differences between the studied groups in terms of ejection fractions, LVEDD, and LVESD (P>0.05).
(4) The RAMT group had significantly larger peak and mean pressure gradients than the conventional group (P=0.01).
(5) The incision length in the RAMT group was considerably less than in the traditional group (5.5 ± 0.5 vs. 14.5 ± 0.7 cm, P=0.0001).
(6) Patients in the RAMT group had a longer CBP time (189.1 ± 44.5 vs. 166.6 ± 24.2 min, P=0.031) and cross-clamping time (141.9 ± 32.4 vs. 118.0 ± 19.5 min, P=0.003), with nearly equal operative time between the two procedures, and no cases in the RAMT group were converted to conventional sterornotomy.
(7) There were no significant differences in the difficulty of weaning off CPB, the requirement for pharmacological support, DC chock, or the need for pacemakers across the study groups.
(8) RAMT-assisted minimally invasive AVR was linked with a reduced output of chest drain (356.4 ± 98.8 vs. 535.2 ± 212.1 ml) and a decreased incidence of blood component consumption (P=0.01).
(9) RAMT was associated with a shorter mechanical ventilation time (4.8 ± 2.2 h in the RAMT group versus 7.0 ± 1.9 h in the conventional group), a shorter time to mobilization (7.1 ± 2.8 h in the RAMT group versus 10.2 ± 3.9 h in the conventional group), a shorter ICU length of stay (39.0 ± 8.3 h in the RAMT group versus 55.7 ± 13.4 h in the conventional group), and a shorter hospital stay (5.4 ± 0.6 days in the RAMT group versus 7 ± 1.9 h in the conventional group).
(10) When compared with the conventional group, minimally invasive AVR via RAMT was not significantly associated with a lower incidence of postoperative pharmacological support, no heart block, or neurological deficit, despite the RAMT group having a higher incidence of postoperative fever and an equal incidence of AF.
(11) When compared with the conventional group, minimally invasive AVR by RAMT was linked with a lower postoperative pain score (4.4 ± 1.8 vs. 6.0 ± 1.9) and reduced doses of analgesic consumption (2 vs. 4), with P=0.01.
(12) In terms of cosmetic score, patients in the RAMT group scored significantly higher than those in the traditional group (P=0.01). In terms of patient satisfaction, patients in the RAMT group scored insignificantly higher than those in the conventional group (P>0.05).
(13) According to the total cost-effectiveness plane, traditional sternotomy surgery is much less

expensive than RAMT (88 639.6 ± 9345.4 LE vs. 111 250.4 ± 1626.3 LE, respectively), with *P*=0.001.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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