Al-Azhar International Medical Journal

Volume 4 | Issue 11 Article 18

2023
Section: Cardiovascular

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How to Cite This Article

Laag, Galal Farrag Abd El Haleem; Gamil, El-Husseiny El-Husseiny; and ElMoaty, Haythm Mohamed Abd (2023) "Early Outcome of Minimally-Invasive Aortic Valve Replacement through Mini Sternotomy versus Conventional Approach," *Al-Azhar International Medical Journal*: Vol. 4: Iss. 11, Article 18.
DOI: https://doi.org/10.58675/2682-339X.2072

ORIGINAL ARTICLE

Early Outcome of Minimally Invasive Aortic Valve Replacement Through Mini-sternotomy Versus Conventional Approach

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Abstract

Background: **Currently, minimally invasive approaches are widely used in the field of cardiothoracic surgeries. The main objective of these approaches is to maximize patient satisfaction regarding the cosmetic shape of the wound, patient comfort, and rapid attainment of normal life. In addition, these approaches are thought to improve patient-related surgical morbidity, length of hospitalization, and total financial burden.**

Objective: **To compare early surgical outcomes during hospital stay after aortic valve surgeries using mini-sternotomy and conventional full-sternotomy approach.**

Patients and methods: **Our research was a prospective, comparative, nonrandomized study. It included 60 patients with aortic valve disease (AVD) who required aortic valve surgery divided into two groups [group I (MSAVR, aortic valve replacement surgery through mini-sternotomy) ($n = 30$) and group II (FSAVR, aortic valve replacement surgery through full-sternotomy) ($n = 30$)]. The study was conducted at El Hussien University Hospital and Nasser Institute Hospital from March 2019 to August 2022.**

Results: **This study showed that MSAVR shows better cosmetic appearance, less postoperative pain, shorter post-operative ventilation time, shorter ICU and hospital stay, less blood transfusion, and more satisfaction to the patients. However, there was no significant difference in operative and early postoperative mortality.**

Conclusion: **Surgical management of AVR via J-shaped partial upper sternotomy is a safe and effective technique as FSAVR and is associated with excellent postoperative outcomes.**

Keywords: Conventional approach, Mini-sternotomy, Minimally invasive aortic valve

1. Introduction

For a long time, median sternotomy was the most commonly used approach. However, it did not achieve patient satisfaction due to cosmetic reasons, especially among young women.[1]

The standard surgical technique used for aortic valve replacement is full median sternotomy, which has been through many enhancements in operative techniques that led to a mortality decrease.[2]

Currently, the availability of minimally invasive surgeries and percutaneous interventions makes them preferred over conventional approaches. One of those interventions was deployed in aortic valve replacement through mini-sternotomy. Being an anterior structure, the aorta can be easily reached, exposed, and cannulated. This enabled us to replace the aortic valve through this feasible technique that can be done in any institute.[3]

Many researchers have reported an association between mini-sternotomy and minimal postoperative pain and incidence of AF, which in turn minimized the use of postoperative narcotic drugs, blood, and blood product transfusion within the first 3 days after surgery. This was explained by a small-sized mediastinal dissection and smaller chest retractor spreading.[4]

Accepted 19 June 2023.
Available online 24 January 2024

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https://doi.org/10.58675/2682-339X.2072

All these factors contributed to earlier ICU and hospital discharge compared with those who had full sternotomy.[5]

It is noteworthy that mini-sternotomy patients had major advantages regarding pulmonary function, earlier extubation, and rapid mobilization. They showed easier rehabilitation and prompt regain of their daily activities. Moreover, better patient satisfaction and efficient deployment of healthcare resources were achieved.[6]

2. Patients and methods

The proposal of had been reviewed by ethical committee in October 2022 and got the ethical approval.

This study was a prospective, nonrandomized, comparative study of 60 patients with isolated aortic valve disease (AVD) requiring aortic valve replacement. This study was performed at El Hussien University Hospital and Nasser Institute Hospital from March 2019 to August 2022.

Thirty patients underwent AV surgery by upper mini-sternotomy with central cannulation (group I), while the other 30 patients underwent traditional full-median sternotomy (group II).

Patients with rheumatic or degenerative and congenital aortic valve disease, aged 20–70 years, undergoing elective isolated aortic valve replacement, left ventricular function more than 40 %, and BMI less than 30 were included in this study. Patients more than 70 years old, who underwent previous cardiac surgeries, urgent intervention, small aortic annulus, and combined with other cardiac surgery were excluded.

All our patients underwent history taking, clinical examination, laboratory investigation, ECG, echocardiography, plain chest radiograph, computed tomography chest, and coronary angiography. Preoperative age, sex, and BMI, operative X-clamp, total bypass, and total operative time were collected. Postoperative ventilation time, ICU stay, bleeding, blood transfusion, arrhythmia, wound infection, total hospital stay, and operative and hospital mortality were collected and compared.

2.1. Operative procedures

All patients were positioned in the supine position, and necessary peripheral arterial and venous access was installed for hemodynamic monitoring, and then general anesthesia was initiated. Conventional cardiopulmonary bypass with a nonpulsatile flow was used, and myocardial preservation was performed using intermittent cold blood cardioplegia every 40 min.

2.2. Surgical techniques

2.2.1. MIAVR through upper mini-sternotomy

After defining the substernal notch, a skin incision was carried out 2 cm below it, then it was extended through the midline until it reached the level of the fourth interventional cardiologists (ICS). Then, the standard saw was deployed to conduct the manubrio-sternotomy that was completed downwards with a gradual deviation to the right to form a 'J' shape with the transverse limb at the same level as the fourth ICS. The internal mammary artery was carefully spared. Good exposure was achieved through the removal and dissection of thymic fat. After the opening of the pericardium, it was sutured to the skin through a silk suspension on both margins of the wound. The establishment of cardiopulmonary bypass (CBP) was attained by the standard aorto-caval cannulation with a double-stage venous cannula. Following aortic cross-clamping, the cardioplegia site is chosen according to the valve condition. It was delivered into the root of the aorta in AS, and ostiae in AR.

Insertion of the left ventricular vent through the right superior pulmonary vein was performed. In all participants, excision of AV was carried out. Then, it was substituted by a prosthetic mechanical valve using 2/0 Ethibond sutures with Teflon pledges. Mobility of the leaflet was tested followed by halting the pulmonary vein vent during the closure of the aortotomy and repositioning the patient in the anti-Trendelenburg posture to regain the blood filling of the LV apex.

After aortotomy closure, venting of the ascending aorta took place. With the help of manual lungs ventilation, pulmonary vein vent, and subtle heart filling, the air was evacuated. Drainage of the right pleura was attained by insertion of a 38-Fr chest drain; another 36-Fr chest drain was placed medially to the previous one in the chest and placed over the ascending aorta. Pacemaker wiring was done before the bypass ended while the heart was nearly empty; then the bypass was gradually stopped. After checking the hemostasis, re-approximation of the upper sternum took place with sternal steel wires transversally. We faced no intraoperative death.

2.2.2. Full-median sternotomy

After defining the sternal notch, a vertical midline cutaneous incision was carried out 2 cm below it; then, it was extended to the xiphoid tip. Sometimes, the incision extends below it by a few centimeters. Following air evacuation, cross-clamping was removed and patients were weaned from bypass as

usual. Layers' closure was completed on two mediastinal chest drains after checking hemostasis.

2.3. Statistical analysis

IBM Statistical Package for the Social Sciences (SPSS) software (SPSS Inc., Chicago, Illinois, USA) was deployed in statistical analysis. Categorical variables were compared using the χ^2 test and/or Fisher's exact test; however, continuous variables were compared using a nonpaired *t*-test; normally distributed variables (parametric data) were described in the form of the mean ± SD. Also, the 95 % confidence interval was depicted. The *P* value was considered statistically significant below the value of 0.05 %.

3. Results

According to demographic data, no significant difference was detected between groups in terms of sex, age, weight, and BMI with *P* values of 0.243, 0.124, 0.686, and 0.939, respectively (Table 1).

According to preoperative echocardiography, the two groups were fairly similar in LV end-diastolic volume, end-systolic volume, and the mean pressure gradient through AV and LV ejection fraction with *P* values of 0.603, 0.436, 0.354, and 0.110, respectively (Table 2).

Aortic cross-clamp (X clamp) time: the mean X clamp time was 61.07 min in group I compared with the mean X clamp time of 50.37 in group II with a *P* value of 0.004, which is highly significant. The mean total CPB estimated time was 99.40 min in group I compared with 81.37 min in the other group with a *P* value of 0.002, which is highly significant. However, the total operative time in hours in both groups was nearly equal with a *P* value of 0.375 which is not significant (Table 3).

Table 1. Comparison of demographic data between both groups.

Demographic data	Group I	Group II	*P* value
Sex [*n* (%)]			
Female	10 (33.3)	6 (20.0)	0.243
Male	20 (66.7)	24 (80.0)	
Age			
Mean ± SD	39.97 ± 12.70	45.30 ± 13.72	0.124
Range	15–60	19–70	
Weight			
Mean ± SD	76.93 ± 12.62	78.40 ± 7.44	0.585
Range	40–100	60–95	
BMI			
Mean ± SD	26.41 ± 2.58	26.46 ± 2.11	0.939
Range	22.8–30	23–30	

Table 2. Comparison between preoperative echocardiography data between both groups.

Preoperative echocardiography	Group I	Group II	*P* value
LVEDD (cm)			
Mean ± SD	5.70 ± 0.74	5.59 ± 0.88	0.603
Range	4.2–7	4.2–7	
LVESD (cm)			
Mean ± SD	3.68 ± 0.66	3.82 ± 0.72	0.436
Range	2.6–5.2	2.9–5.6	
Mean PG			
Mean ± SD	41.6 ± 13.22	46 ± 14.9	0.354
Range	33–74	24.8–74	
LVEF (%)			
Range	0.57 ± 0.06	0.55 ± 0.06	0.110
Range	0.44–0.66	0.44–0.7	

Table 3. Comparison of operative data between both groups.

Operative data	Group I	Group II	*P* value
X-clamp time			
Mean ± SD	61.07 ± 16.07	50.37 ± 11.23	0.004
Range	40–90	35–80	
Total bypass			
Mean ± SD	99.40 ± 23.19	81.37 ± 19.76	0.002
Range	60–150	50–130	
Total operative time (h)			
Mean ± SD	3.25 ± 0.49	3.37 ± 0.52	0.375
Range	2.5–4.5	2.5–5	

Regarding postoperative data, there were significant differences reported between the studied groups regarding ventilation time (VT), inotropic support, total tube drainage, ICU stay, and total hospital stay with *P* values of 0.001, 0.002, 0.001, 0.001, and 0.001, respectively. However, the groups

Table 4. Comparison of postoperative data between both groups.

ICU data	Group I	Group II	*P* value
Ventilation time (h)			
Mean ± SD	10.17 ± 3.82	14.50 ± 3.81	0.001
Range	6–18	8–24	
Inotropic support [*n* (%)]	2 (6.7)	12 (40.0)	0.002
Total drain (ml)			
Median (IQR)	150 (150–200)	250 (200–300)	0.001
Range	150–900	150–1100	
Amount of blood transfusion (U)			
Mean ± SD	1.17 ± 0.58	1.63 ± 1.06	0.172
Range	1–3	1–5	
ICU stay (h)			
Mean ± SD	33.80 ± 11.89	51.77 ± 14.83	0.001
Range	22–72	36–96	
Hospital stay (days)			
Mean ± SD	9.05 ± 2.52	12.3 ± 2.90	0.001
Range	6–15	7–20	

did not vary from each other regarding the amount of blood transfusion with a *P* value of 0.172 (Table 4).

Regarding postoperative complications, significant differences were noted between both groups regarding pain score, arrhythmia, and patient satisfaction with *P* values of 0.001, 0.012, and 0.001, respectively. Nevertheless, they did not show significant differences in terms of bleeding, reoperation, wound infection, pleural and pericardial effusion, and need for permanent pacing with *P* values of 0.161, 0.161, 0.166, 0.448, and 0.982, respectively (Table 5).

Postoperative echocardiography showed no significant differences between both groups in LV end-diastolic dimension, end-systolic dimension, the mean pressure gradient through the implanted prosthetic AV, and LV ejection fraction with *P* values of 0.027, 0.639, 0.311, and 0.022, respectively. Also, there were no malfunction valves, endocarditis, paravalvular leakage, or prosthetic valve failure in both groups (Table 6).

Table 5. Comparison of postoperative complications between both groups.

Postoperative complications	Group I	Group II	*P* value
Bleeding [*n* (%)]			
No	29 (96.7)	26 (86.7)	0.161
Yes	1 (3.3)	4 (13.3)	
Reoperation [*n* (%)]			
No	29 (96.7)	26 (86.7)	0.161
Yes	1 (3.3)	4 (13.3)	
Wound infection [*n* (%)]			
No	27 (90.0)	23 (76.7)	0.166
Yes	3 (10.0)	7 (23.3)	
Early postoperative cerebral and renal complication [*n* (%)]			
No	30 (100.0)	29 (96.7)	0.313
Yes (renal impairment)	0	1 (3.3)	
Arrhythmia [*n* (%)]			
No	25 (83.3)	13 (43.3)	0.012
AF	3 (10.0)	11 (36.7)	
SVT	1 (3.3)	5 (16.7)	
CHB	1 (3.3)	1 (3.3)	
Need for permanent pacemaker [*n* (%)]			
No	29 (96.7)	29 (96.7)	1.000
Yes	1 (3.3)	1 (3.3)	
Mortality [*n* (%)]			
No	30 (100.0)	30 (100.0)	–
Yes	0	0	
Pain score			
Mean ± SD	2.67 ± 0.80	4.44 ± 1.03	0.001
Range	1.5–4	3.2–7	
Patient satisfaction [*n* (%)]			
Dissatisfied	1 (3.3)	6 (20.0)	0.001
Satisfied	11 (36.7)	24 (80.0)	
Very satisfied	18 (60.0)	0	
Pleural and pericardial effusion [*n* (%)]			
No	27 (90.0)	25 (83.3)	0.448
Yes	3 (10.0)	5 (16.7)	

Table 6. Comparison of postoperative echocardiography between both groups.

Postoperative echocardiography	Group I	Group II	*P* value
LVEDD (cm)			
Mean ± SD	5.62 ± 0.73	5.12 ± 0.98	0.027
Range	3.8–7.1	3.38–7	
LVESD (cm)			
Mean ± SD	3.77 ± 0.67	3.68 ± 0.75	0.639
Range	2.6–5.3	2.7–5.6	
Mean PG			
Mean ± SD	14.34 ± 52	13.33 ± 3.66	0.311
Range	8–20	8–19	
LVEF (%)			
Mean ± SD	0.55 ± 0.05	0.51 ± 0.03	0.022
Range	0.45–0.6	0.44–0.58	

4. Discussion

This study is a two-center experience regarding upper mini-sternotomy in patients with aortic valve diseases (Al Hussein Hospital-Al-Azhar University and Nasser Institute Hospital).

Our study included 60 patients with isolated AV disease divided into group I upper mini-sternotomy ($n = 30$) and group II full sternotomy ($n = 30$).

In our study, the two groups did not show any significant differences regarding age, sex, and BMI with *P* values of 0.243, 0.124, and 0.939, respectively, which is in the same line with Reser et al.,[7] El-Husseiny et al.,[1] and Sarawy et al.[8]

Regarding preoperative echocardiography, there were no significant differences between the two groups regarding left ventricular end-diastolic and end-systolic dimensions, mean transvalvular pressure gradient, and ejection fraction with *P* values of 0.603, 0.436, 0.354, and 0.110, respectively, which is similar to Mubarak et al.[9] and Miceli et al.[10]

Miceli et al.[10] reported a mean age of 67.2 ± 12.5 years in other studies.

According to operative data, the mean aortic cross-clamp time in minutes was 61.07 ± 16.07, total bypass time 99.40 ± 23.19, and the total operative time was 3.25 ± 0.49 h in group I compared with 50.37 ± 11.23 min, 81.37 ± 19.76 min, and 3.37 ± 0.52 h, respectively, in group II, with *P* values between the two groups being 0.004 for the cross-clamp time, 0.002 for the total bypass time, and 0.375 for the total operative time, which showed a significant statistical difference regarding cross-clamp time and total bypass time, but the total operative time was not highly significant. These results agree with Van der Merwe et al.[11] and Neely et al.[12]

However, El-Husseiny et al.[1] documented that approaches (mini-sternotomy and right anterior thoracotomy) do not alter the cross-clamp time and total bypass time. Their results show no significant

difference between the two approaches in cross-clamp time nor the total bypass time compared with full sternotomy.

In our study, the mechanical ventilation time was 10.17 ± 3.82 h in group I, whereas it was 14.50 ± 3.81 h in group II, with a *P* value of 0.000. The mean duration of ICU stay was 33.80 ± 11.89 h, in group I, whereas it was 51.77 ± 14.83 h in group II with a *P* value of 0.001. This agrees with the Amr[13] study, and the large meta-analysis by Phan et al.[14] However, this does not agree with Kaczmarczyk et al.[15] as the average length of stay in the ICU was 81.6 ± 20 h for the upper mini-sternotomy approach.

The need for postoperative inotropic support was less in mini-sternotomy with a *P* value of 0.002, which is in contrast with other studies such as those of Ahmed et al.[16]

In our study, total hospital stay was significantly less in group I than in group II with a *P* value of 0.001 and this result agrees with El-Husseiny et al.,[1] Sarawy et al.,[8] and Khoshbin et al.[5]

Regarding total drain amount and need for blood transfusion, they were low in the mini-sternotomy group with *P* values of 0.001 and 0.002, respectively, owing to small incisions and small row areas, which minimized bleeding and need for blood transfusion. This agrees with Phan et al.,[14] where transfusion requirements were significantly reduced in mini-sternotomy AVR patients when compared with full-sternotomy patients (36 vs. 52.4 %, $P < 0.001$).

Wound infection in both groups was superficial and there was no deep sternal wound infection or mediastinitis in both groups but the rate was low in UMS (10 %) compared with FS (23 %). This is similar to Sharony et al.[17] and Gilmanov et al.[18]

There was no significant statistical difference between group I and group II in terms of postoperative cerebral and renal complications with a *P* value of 0.313, which agrees with, the recent meta-analysis of propensity-matched studies comparing the two techniques that found no differences in the incidence of postoperative CVA.[19] These results are consistent with data obtained in the present research, where the rate of CVA being not significant between the two groups (FSAVR, aortic valve replacement surgery through full-sternotomy 1.3 %, aortic valve replacement surgery through mini-sternotomy (MSAVR) 1.9 %, $P = 0.64$).[12,18]

Mini-sternotomy is safe even in patients with poor renal function and is not associated with an increased risk of dialysis. These findings align with results obtained from meta-analysis and other retrospective studies.[20]

In our study, postoperative AF was 36.7 % in FS and 10 % in UMS; SVT was 16.7 % in FS and 3.3 % in UMS; CHB was 3.3 % in both groups with one patient requiring PPM implantation. In both groups, the *P* value for arrhythmia was 0.012, which is statistically significant and similar to the study of Luciani and Lucchese,[4] but in contrast with the study of Torky et al.[21] MS was not significantly associated with new-onset complete heart block after AVR ($P = 0.16$). However, there is no significant difference in postoperative AF.

Postoperative pain was highly statistically different between UMS and FS patients with the pain score in the first 72 h following surgery had a *P* value of 0.000, which is in the same line with both meta-analyses[11,14] and randomized control trials.[22]

There was no operative and in-hospital mortality in our study, which is in the same line with several studies that have demonstrated no significant difference in 30-day mortality or short-term and long-term survival rates between these approaches.[17] In Sharony et al.,[23] hospital mortality and major morbidity were identical in the mini-sternotomy and full-sternotomy groups: 5.6 versus 7.3 % ($P = 0.45$) and 13.3 versus 14.2 % ($P = 0.79$), respectively.

Our study showed that the UMS group had better wound cosmetics and patient satisfaction with UMS 1 % dissatisfied, 11 % satisfied, and 18 % very satisfied with *P* values of 0.001, which is in line with Ghanta et al.[24] and Sarawy et al.[8]

As regards postoperative effusion, there was no statistically significant difference between both groups with a *P* value of 0.448 similar to Brown et al.[25] Van der Merwe et al.[11] reported that 10 % of patients suffered from postoperative pleural effusion that required drainage.

5. Conclusion

The J-shaped partial upper sternotomy AVR approach showed equivocal safety and effectiveness as full-sternotomy AVR. In addition, it showed better postsurgical outcomes regarding morbidity and mortality with shortening of hospital stay and recovery time, and minimizing the need for blood transfusion as a result of minimal bleeding and tissue trauma. Patients reported more cosmetic and overall satisfaction. The only drawbacks were longer cross-clamping and CPB time. Therefore, we support the minimal access approach to be used on a routine basis for isolated AVR.

Conflicts of interest

The authors have no financial interest to declare in relation to the content of this article.

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