Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2023.236426.2893 Volume 29, Issue 6, November 2023
Manuscript ID ZUMJ-2309-2893
DOI 10.21608/ZUMJ.2023.236426.2893
ORIGINAL ARTICLE

Comparing Mini-Sternotomy and Standard Sternotomy for Aortic Valve Replacement in Open Heart Surgeries

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Submit Date 2023-09-14
Accept Date 2023-09-20

ABSTRACT

Background: Aortic valve replacements (AVRs) are being conducted with minimal risk of complications. Reduced blood loss, shorter hospital stays, preservation of lung function, and lower incidence of atrial fibrillation are all benefits of less invasive techniques created for the benefit of patients. We aimed in this work to compare the outcome of patients undergoing aortic valve replacement in open heart surgeries via standard and mini sternotomy maneuvers (J-shaped).

Methods: We conducted a retrospective cohort study for twenty-four cases who had aortic valve disease that necessitates aortic valve surgery at the Cardiothoracic surgery department of Zagazig University Hospital. Twelve patients underwent aortic valve replacement by standard sternotomy and the other twelve patients by mini sternotomy (J shaped to the right third intercostal space).

Results: All the total bypass, aortic cross-clamp times, as well as operative times, were significantly longer in the mini-sternotomy group ($P < 0.001$). Mechanical ventilation (MV) duration as well as hospital stay were significantly shorter in the mini (p values=0.04 and 0.001 respectively) while total drain was significantly higher in the standard group (p=0.001). Post-operative pain score and pethidine dose were significantly higher in the standard sternotomy group. Incidence of infection as well as blood transfusion were significantly higher among the standard group (p=0.02 and 0.007 respectively).

Conclusions: Mini sternotomy appears advantageous due to shorter mechanical ventilation times, potentially facilitating quicker postoperative recovery. It may also offer improved postoperative pain control. The patient's preferences, risk considerations, and intended outcomes should all be considered in making the decision.

Keywords: Standard Sternotomy; Mini-Sternotomy; Aortic Valve Replacement; Open Heart Surgery.

INTRODUCTION

The mortality and morbidity rates associated with aortic valve replacement surgeries have decreased dramatically in recent years. For the sake of the patient, less invasive methods were developed in the 1990s, leading to less pain and better aesthetic results [1].

Because of the small incision size, surgical complications may arise that are not encountered during a standard aortic valve replacement (AVR) by a median full sternotomy. Self-educated patients, on the other hand, frequently request less invasive procedures. Upper or lower mini sternotomy, minor right anterolateral thoracotomy, right parasternal incision, transverse sternotomy, as well as inverse-T partial sternotomy are all examples of minimally invasive approaches to AVR [2].

Reduced blood loss, fewer blood transfusions, shorter hospital stays, lung function preservation, lower frequency of atrial fibrillation, and quicker return to functional activity are only some of the advantages observed in studies using the less invasive approach [3]. Some potential drawbacks of minimally invasive techniques have been documented, including increased cross-clamp time (CCT) and cardiopulmonary bypass (CPB) time, and paravalvular leak risk [4].

In our hospital, replacing an aortic valve typically necessitates making a median full sternotomy (MFS). A new method known as minimally invasive aortic valve replacement (MIAVR) has recently gained popularity. The literature suggests that the benefits of MIAVR are debatable. Here, we present a comparison of MIAVR and MFS access in terms of early postoperative outcomes like wound infections, blood loss, post-operative recovery, morbidity, as well as death [4]. Thats why we aimed in this work to compare the outcome of patients undergoing open heart surgery for AVR via standard and Mini-sternotomy maneuvers (J-shaped).

METHODS

We conducted a retrospective cohort study for patients who had aortic valve disease that necessitated aortic valve surgery at the Cardiothoracic Surgery Department of Zagazig University Hospital from July 2022 to July 2023. The estimated sample was twenty-four cases including twelve cases in each group. The mean cardiopulmonary bypass (CPB) time was 82.7+_23.5 vs 59.6+_15.1 in the intervention vs. control group at 80%. Power and 95% CI.

The cases were split into two groups: Group (A): involved twelve cases who underwent aortic valve surgery through standard sternotomy. Group (B): involved twelve cases who underwent aortic valve surgery through mini-sternotomy (J-shaped).

After institutional review board approval of IRB (#10111/2-11-2022), written informed consent was obtained from all participants. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion criteria: Cases aged between 20 and 70 years old who presented with a severe and/or symptomatic aortic valve stenosis or regurge that necessitates an isolated AVR.

Exclusion criteria: Cases who had any of the following: Double valve replacement /or combined CABG, AVR, severe comorbidities, previous cardiac surgery, severe lung disease, active infection, known bleeding disorders, severe hemodynamic instability, porcelain aorta, patients with ejection fraction less than 40 %.

Pre-operative preparation

All patients were considered to complete history taking including age, sex, occupation, history of chest pain, fatigue, fainting, hemoptysis, and/or shortness of breath. General and local examinations were done; vital signs, general look i.e., cachexia, lower limb examination, local examination of the heart including inspection, palpation, and auscultation of murmur related to aortic valve. Radiographic assessment included: chest X-ray, CT-chest and echocardiogram were done in all cases and Coronary- Angiography was done if the male patient was >50 years old or female patient >45 years old. Laboratory investigations included: complete blood count, kidney function test , liver function test as well as coagulation profile for preparation of the surgery.

Surgical approaches

One of the two study groups underwent standard sternotomy AVR, while the other was operated for mini sternotomy AVR (J-shaped).

Anesthesia: Before initiating the surgery, the patient was placed under general anesthesia. This involved administering anesthetic agents intravenously to induce a state of unconsciousness. Endotracheal intubation was performed to secure the airway and facilitate mechanical ventilation. Arterial and central venous lines were inserted to monitor blood pressure, and central venous pressure, and administer medications as needed.

Standard sternotomy AVR: After identifying the xiphoid process and the suprasternal notch, a median and vertical lines were drawn to delineate the incision. Between these two places, the periosteum was separated, and bleeding points cauterized with the electrocautery, and the midline was readily incised with cautery by severing the subcutaneous tissue and the underlying pectoral fascia between fibers of the pectoralis major muscle.

After that, we removed the periosteum from the sternum and cauterized the bleeding areas. To prevent excessive bleeding, the transverse venous arch in the jugulum had to be located and divided. Then we separated the sternum and the sternoclavicular ligament using blunt digital dissection on the sternum's back. The xiphoid process was freed from the diaphragm's underlying tissue via blunt digital dissection, the last stage before sawing. After the thymus gland was removed, the pericardium was cut. Adequate exposure may typically be achieved with the use of stay sutures made of strong silk and the suturing of the pericardium to the borders of the incision.

Cannulation - Aortic and Venous: Cannulation was a critical step in establishing CPB and maintaining adequate perfusion during the surgery. Two cannulas were utilized: Aortic Cannulation: A cannula was introduced into the ascending aorta via a purse-string suture, and venous Cannulation: A two-stage venous cannula was placed into the right atrium through the vena cava. The proximal portion drained deoxygenated blood from the superior vena cava, and the distal portion was positioned in the inferior vena cava to ensure complete venous drainage during CPB. CPB was established to maintain oxygenated blood circulation while the heart was temporarily arrested for valve replacement.

Valve Replacement steps: The AVR procedure involved the removal of the diseased aortic valve and its replacement with a prosthetic valve. The following steps outlined the process: Aortic cross-clamping: A clamp was placed across the ascending aorta above the aortic valve to arrest blood flow during valve replacement. Aortotomy: An incision was made in the aorta to expose the diseased valve. Valve Excision: The damaged aortic valve leaflets were excised, and any calcifications or debris were carefully removed. Annular Preparation: The annulus (valve's base) was sized and prepared for the placement of the prosthetic valve. Prosthetic Valve Implantation: The chosen prosthetic valve (mechanical or bioprosthetic) was secured within the annulus using sutures or other fixation methods. Closure: the aortotomy incision was sutured, and the aortic cross-clamp was removed to restore blood flow. De-Airing: The heart was carefully de-aired to eliminate any air bubbles from the cardiac chambers, ensuring optimal cardiac function. Weaning off CPB: The patient's heart was gradually allowed to resume its pumping function as the CPB flow was gradually decreased. Decannulation: Once the heart was stable, the cannulas were removed, and any bleeding was controlled. Closure: The sternum was closed using stainless steel wires, and the chest was closed layer by layer.

Mini sternotomy AVR (J-shaped mini-sternotomy): A 5–8-centimeter midline skin incision was made while the patient was under general anesthesia and lying supine. The incision began one centimeter below the suprasternal notch and extended downward. Care was taken to protect the right internal mammary artery while the sternum was carefully separated vertically and then transected horizontally at the level of the right third or fourth intercostal gap. After making a J-shaped incision in the patient's chest, surgeons removed the thymus and opened the pericardium longitudinally by inserting a small retractor between the sternal margins. Adequate exposure may typically be achieved with the use of stay sutures made of strong silk and the suturing of the pericardium to the borders of the incision. A single venous cannula was used to access the ascending aorta, and a 20 or 22-gauge straight aortic cannula was used to access the aortic root, where cardioplegia and de-airing were administered. Cardioplegia was injected into the aortic root after aortic cross-clamping, which was performed with a standard right-angled aortic cross-clamp without obstructing the surgical field. It is the same as with the standard sternotomy group once the CPB has been started.

Operative and postoperative follow-up: Both study groups were followed up in the early postoperative course and postoperative follow-up period of one month. Collected data included: Operative: (CPB time, aortic cross-clamp time, operation time, and size of the prosthetic valve). Post-operative: (Cases turned from j-shaped to full sternotomy operation, durations of mechanical ventilation, ICU as well as hospital stay, total chest tube drain, inotropic support, pain score and analgesic dosage, and echocardiography follow-up before discharge and one month after).

Statistical Analysis

SPSS 26.0 for Windows was used for data collection, tabulation, and statistical analysis (SPSS Inc., Chicago, IL, USA). Mean SD Range was used to represent quantitative data, whereas numbers and percentages were used to represent qualitative data. A t-test was used to analyze quantitative information.

RESULTS

Non statistically significant differences were found between the groups as regards age, BMI, or sex distribution with p values= 0.496, 0.688, 0.56, respectively (Table 1).

Aortic cross clamp time, operative time as well as total bypass time were significantly longer in mini sternotomy group with P value< 0.001 (Table 2).

Compared to the standard group (A), the mini sternotomy group (B) had shorter MV and hospitalization times, whereas group (A) had significantly higher total drain (Table 3). Moreover, post operative echocardiographic data comparison between the two groups showed no significant differences in valve function parameters, including mean gradient, peak gradient, Left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), and ejection fraction at discharge and 4 weeks follow-up (p >0.05 for all comparisons). No paravalvular leakage was observed in postoperative echo (Table 4).

In our study, the standard sternotomy group exhibited significantly higher immediate operative pain scores (P-value = 0.028) and maintained elevated pain scores from days 2 to 4. Additionally, this group received significantly higher immediate operative pethidine doses (P-value = 0.0136), and this trend persisted with higher pethidine doses administered to the group members from days 2 to 4, so pethidine dose was significantly higher (Table 5).

No significant differences were seen between groups in terms of inotropic support or reopening for bleeding, although there were strong correlations between standard sternotomy group and infection and blood transfusion (Table 6).

Table 1: Demographic data distribution between studied groups

			Standard sternotomy group N=12	Mini sternotomy group N=12	P
Age (years)			40±5	42 ±7	0.496
BMI			24±1.5	25 ±1.7	0.688
Sex	**Male**	**N**	6	7	0.56
		%	50.0%	60.0%	
	Female	**N**	6	5	
		%	50.0%	40.0%	

BMI: body mass index

Table 2: Comparison of aortic cross clamp time, total bypass time and operative time between studied groups

	Standard sternotomy group N=12	Mini sternotomy group N=12	P
Aortic cross clamp time	55±7	70±10	<0.001**
Total bypass time	70±10	85±11	<0.001**
Operative time	185±17	250±15	<0.001**

*: Significant, **: Highly significant.

Table 3: MV duration, ICU and hospital stay distribution between studied groups

	Standard sternotomy group N=12	Mini sternotomy group N=12	P
Duration of MV (Hours)	8±4.14	5.35±1.8	0.041*
ICU stay (Hours)	47±7	40±5	0.04*
Hospital stay (days)	7±1.2	4.6±1.5	0.001**
Total drain (ml)	503±99.52	308±80	0.00**

MV: Mechanical ventilation, ICU: Intensive care unit, *: Significant, **: Highly significant

Table 4: Comparison of the two procedures as regards Post-operative ECHO data

Valve function			
	Standard sternotomy group N=12	Mini sternotomy group N=12	**P**
During Discharge (Mean ±SD)			
Mean gradient	21.9±5.7	23.2 ±4.9	0.56
Peak gradient	36.1±12.7	39.9±11.7	0.45
LVEDD (Cm)	4.55 ± 0.31	4.73 ± 0.46	0.263
LVESD (Cm)	4.02 ± 0.59	3.95 ± 0.63	0.791
Ejection fraction	57.08 ± 3.7	57.58 ± 3.15	0.725
After 4 weeks (Mean ±SD)			
Mean gradient	15.7±5.5	17.7±5.8	0.19
Peak gradient	29.7±10.8	31.9±10.5	0.78
LVEDD (Cm)	4.57 ± 0.31	4.73 ± 0.44	0.297
LVESD (Cm)	4.35 ± 0.31	4.2 ± 0.47	0.366
Ejection fraction	57.67 ± 3.65	58.83 ± 2.92	0.397

LVEDD: Left ventricular end-diastolic diameter, LVESD: left ventricular end-systolic diameter.

Table 5: Post operation follow up pain score using Visual Analogue Scale and Post operation follow up (pethidine) analgesia dose (mg)

	Group A (N = 12)	Group B (N = 12)	P. Value
Immediate post operative	6.5 ± 2.32	4.5 ± 1.83	0.02844*
Day 1 post operation	3.92 ± 2.78	3.08 ± 1.51	0.37085
Day 2 post operation	5.08 ± 2.61	2.83 ± 1.4	0.01528*
Day 3 post operation	4.75 ± 2.3	2.42 ± 0.51	0.00241*
Day 4 post operation	4.33 ± 2.02	2.58 ± 0.51	0.00803*
Post operation follow up (pethidine) analgesia dose (mg)			
	Group A	Group B	P. Value
Immediate post operative	37.83 ± 12.73	25.92 ± 8.64	0.01356*
Day 1 post operation	27.08 ± 10.83	22.67 ± 6.23	0.23375
Day 2 post operation	30.42 ± 11.42	21.83 ± 6.35	0.03299*

Day 3 post operation	28.92 ± 11.33	20 ± 0	0.0123*
Day 4 post operation	26.33 ± 8.21	20 ± 0	0.01387*

*: Significant, **: Highly significant

Table 6: Outcome distribution at pre and post between studied groups

		Groups		P
		Standard sternotomy N=12	Mini sternotomy N=12	
Inotropic support		1	1	0.64
Reopening		1	0	0.31
Superficial wound infection		4	0	0.02*
Transfusion requirement	**0.00**	1	3	0.007 *
	1.00	4	8	
	2.00	4	1	
	3.00	3	0	

*: Significant, **: Highly significant

DISCUSSION

Mini sternotomies have many advantages over traditional sternotomies, including a shorter recovery time and less sternal wound dehiscence and bleeding [5]. However, the surgeon and assistant surgeon are unable to get a good look at the operational field through a mini- sternotomy, and the ascending aorta cannot be reached. It also has the potential to lengthen the duration of the process. For this reason, mini-AVR presents greater technical difficulty for the cardiac surgeon and calls for specialized training [6].

Non statistically significant differences were found between the groups as regards age, BMI, or sex distribution with p values= 0.496, 0.688, 0.56, respectively. In agreement with our results, Abdelwahed et al [7] examined the outcomes of AVR surgeries performed via mini- and standard sternotomies. In terms of age, body mass index, and gender distribution, they found no significant differences across groups.

Our study showed that aortic cross clamp time, operative time as well as total bypass time were significantly longer in mini sternotomy group with P value< 0.001, where aortic cross clamp was 70±10 in mini group and 55±7 in standard group, total bypass time was 85±11 in mini group and 70±10 in standard group, and total operative time was 250 ±15 in mini group and 185±1 in standard group. In line with us, Sarawy et al. [1] who revealed that aortic cross-clamp time among upper mini sternotomy group was 42–116 minutes, whereas in standard group, the range was 45–68 minutes, with a statistical significance. The range of total bypass time (min) in upper mini-sternotomy group was 64–140 min, with mean 107.48 ± 20.06 min, whereas in standard group, the range was 70– 86 min, with mean 75.76 ± 4.06 min, with statistical significance. The range of total operative time in upper mini-sternotomy group was 175–360 min, with mean 308.48 ± 65.51 min, whereas in standard group, the range was 178–258 min, with mean 198.88 ± 18.85 min, with statistical significance. Also, Merk et al. [8] found the same results.

On the other side, A meta-analysis of twenty-three studies published in 2017 compared the operative time for AVR between mini-sternotomy and standard sternotomy. The analysis included a total of 4,534 patients, with 2,115 undergoing mini-sternotomy and 2,419 undergoing standard sternotomies. The results showed that the mean operative time for mini-sternotomy was significantly shorter than for standard sternotomy (138.48 minutes versus 171.88 minutes, respectively; p < 0.0001) [9].

In our study, there was a significant difference regarding mechanical ventilation duration and hospital stay as it was significantly shorter in mini and total drain was significantly higher in full group.

Similar to our study, Ferreira et al. [3] found that MIAVR has been shown to have a quicker recovery time, shorter hospital stays, and needs less rehabilitation resources as compared to traditional surgery**,** as the average length of stay in the ICU was longer (81.6 ± 20 h) for the upper mini-sternotomy approach and the average length of hospital stay was 11±9.0 days for the sternotomy group and 7.1±2.0 days for MS group**.** Also, Sarawy et al [1], also showed that ICU stay was significantly less in mini sternotomy group (32.64 ±12.26 h).

In disagreement with our study, Ferreira et al. [3] found that the mean duration of mechanical ventilation was significantly lower in the standard full sternotomy group (153.9±118.6 min.) compared to the mini-sternotomy group (287.3±138.9 min; P=0.003).

Moreover, post operative echocardiographic data comparison between the two groups showed no significant differences in valve function parameters, including mean gradient, peak gradient, LVEDD, LVESD, and ejection fraction at discharge and 4 weeks follow-up ($p > 0.05$ for all comparisons). No paravalvular leakage was observed in postoperative echo.

On the same side, the study by Hancock et al. [10] comparing valve characteristics between mini-sternotomy (A) and conventional sternotomy groups (B), no significant differences were observed in valve function parameters. Mean gradients and peak gradients for both preoperative and 6-week assessments showed small non-significant variations between the groups. For mean gradient, there was no significant difference between groups, with group A having a mean of 47.9 mmHg and group B having a mean of 47.7 mmHg (0.2 difference, CI: -4.6 to 5.0). Similarly, peak gradient also showed no significant difference between groups, with group A having a mean of 82.3 mmHg and group B having a mean of 77.1 mmHg (5.2 difference, CI: -1.7 to 2.3), with a range of 16 to 152 for group A and 8 to 173 for group B.

We disagreed with the study by Furukawa et al. [11] involving 984 patients, the comparison between minimally invasive cardiac (MIC) surgery and full sternotomy approaches revealed that the mean left ventricular ejection fraction (LVEF) was 60% with a standard deviation of 10% for all patients. The LVEF was slightly lower in the MIC group (58% with a standard deviation of 12%) compared to the sternotomy group. The z-difference was -3.36. This suggests that there was a small but statistically significant difference in LVEF between the two groups, with the sternotomy group showing a slightly higher LVEF than the MIC group.

In our study, the standard sternotomy group exhibited significantly higher immediate operative pain scores (P-value = 0.028) and maintained elevated pain scores from days 2 to 4. Additionally, the standard sternotomy group received significantly higher immediate operative pethidine doses (P-value = 0.0136), and this trend persisted with higher pethidine doses administered to standard sternotomy group members from days 2 to 4.

The increased post-operative pain and analgesia requirement observed in patients undergoing standard sternotomy compared to those undergoing mini-sternotomy can be attributed to the larger incision and greater tissue trauma associated with standard sternotomy. This larger incision disrupts muscles, bones, and nerves to a greater extent, leading to heightened inflammation, nerve activation, and pain signals. Additionally, the greater surgical trauma of standard sternotomy can impact respiratory mechanics, causing discomfort during breathing and further exacerbating pain. Conversely, minimally invasive technique involves smaller incisions, reduced tissue manipulation, and less chest wall trauma, resulting in decreased activation of pain pathways and subsequently lower analgesia needs [10].

Our findings show that there was no significant difference between groups as regard inotropic support, reopening for bleeding but superficial wound infection, blood loss and blood transfusion were significantly higher associated with standard group, and we reported no mortality at both groups.

In agreement with us, Fudulu et al. [12] reported that MIAVR is a safe and effective procedure and performed with comparable morbidity and mortality to conventional AVR. MIAVR results in improved ventilator function, reduced wound infection, shorter hospitalization, and a greater proportion of patients being discharged early to home.

In the study of Sarawy et al [1], in group A (mini sternotomy) the average blood loss in the first 24 h in ml was 150 ± 50.2 and total blood loss in ml was 503 ± 99.6. whereas in group B (standard sternotomy) the average blood loss in the first 24 h in ml was 360± 51.6 and total blood loss in ml was 860 ± 164.6, there was significant difference among both groups regarding blood loss, therefore increase rate of blood transfusion. Recently, Shehada et al. [13] reported that MIAVR was associated with lower rate of autologous blood transfusion.

In the study conducted by Mikus et al. [14], they made a comparison of clinical variables among three groups (full sternotomy, mini sternotomy, and mini thoracotomy). The mortality rate was 8 (4.5%) in Group 1 (full sternotomy), 3 (1.1%) in Group 2 (mini sternotomy), and 1 (0.6%) in Group 3 (mini thoracotomy). The reported p value of 0.013 indicates a statistically significant difference in mortality rates among the three surgical approaches, with the Mini thoracotomy group demonstrating the lowest mortality rate. Like our study, Sarawy et al [1] reported no mortality among both study groups.

Limitations:

The study may be limited by its sample size, which could affect the generalizability of the findings to a broader patient population. A larger and more diverse sample might provide more robust insights. We recommend increasing the period of follow-up: The follow-up period in the study may have been relatively short. Long-term outcomes and complications associated with AVR, such as late valve dysfunction or reoperation rates, were not addressed. Longer-term follow-up would provide a more comprehensive assessment of patient outcomes.

Conclusions

In conclusion, determining which surgical modality, whether standard sternotomy or mini sternotomy (J-shaped), is better for aortic valve replacement hinges on several factors. The choice should be individualized based on patient-specific characteristics and priorities. Mini sternotomy appears advantageous due to shorter mechanical ventilation times, potentially facilitating quicker postoperative recovery. It may also offer improved postoperative pain control. However, it is important to consider that this approach often entails longer surgical durations.

Standard sternotomy, on the other hand, is associated with longer hospital stays and increased postoperative drainage. It also carries a higher risk of postoperative infections and blood transfusions.

The choice should be made in consultation with the patient, considering their preferences, risk factors, and desired outcomes. Surgeons should carefully consider the trade-offs between these approaches, balancing the potential benefits of one against the drawbacks of the other, while considering the specific needs and priorities of the individual patient. It is essential to prioritize patient safety, efficient recovery, and long-term outcomes in making this decision.

Conflict of interest

The authors declared that they have no conflicts of interest with respect to the authorship and/ or publication of this article.

Financial disclosures

This study was not supported by any source of funding.

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To Cite:
osman, D., Mansour, M., mobasher, M., Sobhy, E., Tawfek, A. Comparing Mini-Sternotomy and Standard Sternotomy for Aortic Valve Replacement in Open Heart Surgeries. *Zagazig University Medical Journal*, 2023; (1526-1534): -. doi: 10.21608/zumj.2023.236426.2893