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Original Article

A comparative study between mini versus full sternotomy aortic valve replacement

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Abstract

Background

Aortic valve replacement for treatment of aortic valve diseases is quite common. Minimally invasive procedures have gained a lot of popularity in recent years with the claimed better early postoperative outcomes in comparison with conventional techniques.

Objective

The aim was to compare early postoperative outcomes after ministernotomy versus conventional median sternotomy aortic valve replacement.

Patients and methods

The authors prospectively studied 60 patients who underwent aortic valve replacement surgery at the National Heart Institute between the period of May 2020 and July 2021. A total of 30 patients had aortic valve replacement via upper ministernotomy approach, whereas the other 30 patients had aortic valve replacement using conventional median sternotomy. Early postoperative results were compared with each other.

Results

There was no morality throughout the study. The mean age was 45.8 ± 15.13 years in the conventional group and 51.13 ± 17.8 in the ministernotomy group. Perioperative data showed no significant difference between the two groups, except for aortic orifice (root) diameter, which was wider in the ministernotomy group. The cross-clamp time was 60.33 ± 8.27 in the conventional group and 70.66 ± 6.91 in the ministernotomy group, and the total bypass time was 77.0 ± 8.46 and 88.1 ± 9.55, respectively, with significant difference between the two groups. Postoperative pain levels showed a statistically significant difference and were less severe in the ministernotomy group, and the total hospital stay was shorter in the ministernotomy group, with significant difference between the two groups.

Conclusion

The use of upper ministernotomy approach to replace a diseased aortic valve is safe and can be compared with the conventional median sternotomy approach.

Keywords: Aortic valve replacement, conventional median sternotomy, ministernotomy

Introduction

Aortic valve diseases are one of the most common cardiac lesions all over the world. Severe symptomatic patients suffering from severe aortic stenosis and/or regurge need early intervention to prevent further deterioration of cardiac condition and development of complications. Aortic valve replacement is considered the treatment of choice for these patients. Recent guidelines of the American College of Cardiology and American Heart Association and the current European Society of Cardiology guidelines for the management of aortic valve disease state that surgical aortic valve replacement (AVR) is recommended for symptomatic patients with severe aortic stenosis and/or regurge and asymptomatic patients with severe aortic stenosis and/or regurge who meet the indications for AVR with low or intermediate surgical risk [1].

Conventional median sternotomy AVR is a well-established procedure that can be performed with very low morbidity and

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mortality. Recently, a less-invasive technique was introduced for aortic valve replacement. These techniques have gained a lot of popularity all over the world, and the minimally invasive AVR (mini-AVR) has become a well-known technique in many specialized centers. This was accompanied by increased patient awareness with the increased demand for less-invasive approaches [2–5].

Although results from previous studies have shown similar outcomes with conventional median sternotomy AVR in terms of safety, risk of death, and serious complications, some studied have demonstrated several advantages of minimally invasive approaches, including decreased blood loss with less need for blood transfusion, shorter hospital stay, preserved lung function, less incidence of atrial fibrillation, and early functional activity [6–11]. On the contrary, small incisions with limited exposure associated with ministernotomy AVR, especially in obese patients, may be surgically challenging and carries the risk of unwanted complications, which have been also reported, such as long cardiopulmonary bypass time, long cross-clamp time (CCT), difficulties with de-airing, and increase in the risk of paravalvular leak [12–15]. Despite different conclusions reached from prior clinical studies, there have been few confirmatory large studies.

Patients and Methods

The study was conducted between May 2020 and July 2021 after approval of the ethical committee. A total of 60 consecutive patients who needed isolated aortic valve replacement were studied prospectively at the National Heart Institute, Cairo, Egypt. The studied patients were divided into two groups: group A, which included 30 patients who underwent aortic valve replacement via ministernotomy approach, whereas group B included 30 patients who had their aortic valve replacement via the conventional median sternotomy approach. All preoperative, operative, and postoperative data of those patients were compared with each other for early postoperative outcomes.

The participating patients were subjected to inclusion criteria, which included patients with isolated aortic valve disease who are good candidates for AVR, adult patients 18 years old or above, first-do patients, normal ejection fraction patients (>55%), any weight class including obese patients with BMI >30 kg/m^2, and patients willing to sign a written informed consent. Exclusion criteria were young patients less than 18 years old, patients with associated other valvular or coronary artery diseases, redo patients, patients with small aortic annulus (<2.1 cm^2), patients with low ejection fraction, and patients unable to provide a written informed consent.

The approach for minimally invasive AVR was the partial upper sternotomy approach, which was used in all patients who underwent minimal access surgery. The decision to either the selected patients undergo minimal or conventional approach AVR was taken by operating surgeons without any special preoperative assessment or preparation for the minimal approach group. All participating surgeons in the study were highly qualified with long-term experience in such cases with no restrictions regarding certain staff selection.

The selected cardioplegic solution was the Custodiol Histidine-tryptophan-ketoglutarate (HTK) cardioplegia used in all cases of both groups. There are multiple advantages of Custodiol cardioplegia, which include infrequent single-dose administration as well as adequate myocardial preservation. This is needed especially in minimally invasive procedures, which are long and demanding operations. The rule of Custodiol cardioplegia is to provide smooth uninterrupted surgery together with adequate myocardial protection, which is favorable by most surgeons.

The postoperative pain was addressed through the daily need for analgesic medications as well as the aid of pain charts, which were part of the patient's daily medical records. The patients' subjective pain sensation was analyzed daily, and the pain level was determined according to a scale ranging from 0 to 10 taken regularly by the nursing staff with the help of the patients.

Statistical analysis

Data were collected, tabulated, and statistically analyzed by IBM personal computer and statistical package SPSS version 20 (IBM Corp., Armonk, New York). Two types of statistics were applied:

(1) Descriptive statistics, for example, percentage, mean, and SD.
(2) Analytic statistics: for example:
   (a) Student's *t*-test is a test of significance used for comparison between two groups having quantitative variables.
   (b) χ^2-test was used to study association between two qualitative variables.
   (c) A *P* value of less than 0.05 was considered statistically significant.

Results

There was no mortality in both groups throughout the study. There was no significant difference between both groups regarding preoperative patient variables except for aortic orifice (root) diameter, which was wider in the ministernotomy group. Regarding operative data, the CCT was 60.33 ± 8.27 in the conventional group and 70.66 ± 6.91 in the ministernotomy group, and the total bypass time was 77.0 ± 8.46 and 88.1 ± 9.55, respectively; both showed a statistically significance difference between the two groups. The percentage of tissue valves used to replace the diseased native aortic valve was higher in the ministernotomy group. There was no statistically significant difference regarding postoperative inotropic support, bleeding, and ICU stay (Tables 1–3).

The postoperative pain was more well tolerated in the ministernotomy group than in the conventional group, in either the ICU or the ward period, with significant difference

Table 1: The preoperative, operative, and postoperative data of the median sternotomy group

	Median sternotomy group ($n=30$) [n (%)]
Age (years)	45.8±15.13
Female sex	19 (63.33)
BMI (kg/m^2)	23.45±2.89
DM	23 (76.66)
HTN	23 (76.66)
Smoker	10 (33.33)
Preoperative Echo	
LVEDD (cm)	5.83±0.73
LVESD (cm)	4.33±0.96
EF (%)	52.33±11.01
AO (cm)	2.58±0.30
Pathology	
Stenosis	14 (46.66)
Regurge	10 (33.33)
Double	6 (20.0)
Cause of pathology	
Bicuspid	1 (3.33)
Rheumatic	20 (66.66)
Calcific	7 (23.33)
Degenerative	2 (6.66)
CC time (min)	60.33±8.27
BP time (min)	77.0±8.46
Prosthetic valve	
Tissue	7 (23.33)
Mechanical	23 (76.66)
Size	
19	4 (13.33)
21	6 (20.0)
23	14 (46.66)
25	6 (20.0)
Inotropic support	
Dobutamine	10 (33.33)
Adrenaline	17 (56.66)
Levosimendan	1 (3.33)
Duration of ventilation (h)	22.46±17.52
ICU stay (h)	64.16±29.95
Amount of bleeding (ml)	515.0±204.32
ICU pain degree (0-10)	
5	12 (40.0)
6	17 (56.66)
7	1 (3.33)
ICU complication	
Reopening	1 (3.33)
Heart block	2 (6.66)
Chest infection	1 (3.33)
Wound infection	
SWI	2 (6.66)
DWI	1 (3.33)
Ward pain degree (0-10)	
3	3 (10.0)
4	21 (70.0)
5	6 (20.0)
Total ward stay (days)	7.96±2.52
Total hospital stay (days)	11.76±3.56
Postoperative Echo	
LVEDD (cm)	5.71±0.60
LVESD (cm)	4.25±0.87
EF (%)	52.13±9.22
Mean PG (mm Hg)	11.66±1.72
Max PG (mm Hg)	24.56±3.19

AO, aortic root; BP, bypass time; CC time, cross-clamp time; DM, diabetes mellitus; DWI, deep wound infection; EF, ejection fraction; HTN, hypertension; LVEDD, left ventricular end diastole diameter; LVESD, left ventricular end systole diameter; PG, pressure gradient; SWI, superficial wound infection.

between both groups. The total hospital stay was shorter in the ministernotomy group compared with the conventional group, being 8.86 ± 3.05 and 10.60 ± 3.44, respectively with a significance difference between the two groups (Table 3 and Figs. 1–4).

Discussion

There were no significant differences in mortality or the incidence of major perioperative complications between the two groups. Minimally invasive aortic valve replacement was first introduced in early 1990s [2], and since then, the technique has been amended and refined until it became the main surgical technique in many centers around the world. Although several studies have reported numerous advantages of minimally invasive technique, including less morbidity, superior cosmetic appearance, decreased tissue trauma, reduced blood transfusion, less incidence of atrial fibrillation, preservation of postoperative respiratory function, shorter ventilation time, and shorter hospital stay [6–11], others have also reported a lot of disadvantages, namely, that minimally invasive procedures are surgically demanding techniques with limited field exposure which can increase the cross-clamp and cardiopulmonary bypass time, leading to higher rates of morbidity and mortality [12–15].

Different approaches are available to replace a diseased aortic valve through a limited incision. The most commonly used nowadays are the right minithoracotomy and the upper ministernotomy. In our study, we have chosen the upper ministernotomy approach, as it can provide better exposure with full access to the upper aorta including the arch. This is essentially important when aortic cannulation and cross-clamping have to be gently performed as in case of elderly patients with friable tissues or in patients with severely calcified aorta. Other advantages of this approach include easy conversion to full sternotomy in case of complications; preservation of the right internal mammary artery, which can be sacrificed during the right minithoracotomy approach, leading to decreased sternal healing capacity; and avoidance of femoral incision with its complication, including the risk of

Table 2: The preoperative, operative, and postoperative data of the ministernotomy group

	Ministernotomy group (n=30) [n (%)]
Age (years)	51.13±17.8
Female sex	12 (40.0)
BMI (kg/m^2)	24.93±4.16
DM	17 (56.66)
HTN	18 (60.0)
Smoker	13 (43.33)
Preoperative Echo	
LVEDD (cm)	5.66±0.36
LVESD (cm)	4.11±0.48
EF ()	51.56±6.47
AO (cm)	2.92±0.34
Pathology	
Stenosis	15 (50.0)
Regurge	8 (26.66)
Double	7 (23.33)
Cause of pathology	
Bicuspid	1 (3.33)
Rheumatic	14 (46.66)
Calcific	11 (36.66)
Degenerative	4 (13.33)
CC time (min)	70.66±6.91
BP time (min)	88.1±9.55
Prosthetic valve	
Tissue	16 (53.33)
Mechanical	14 (46.66)
Size	
19	1 (3.33)
21	10 (33.33)
23	11 (36.66)
25	8 (26.66)
Inotropic support	
Dobutamine	9 (30.0)
Adrenaline	18 (60.0)
Duration of ventilation (h)	17.76±11.39
ICU stay (h)	55.76±32.56
Amount of bleeding (ml)	544±225.01
ICU pain degree (0-10)	
4	15 (50.0)
5	13 (43.3)
6	2 (6.66)
ICU complication	
Reopening	1 (3.33)
Heart block	2 (6.66)
Chest infection	1 (3.33)
Renal Impairment	1 (3.33)
Wound infection	
SWI	1 (3.33)
DWI	0
Ward pain degree (0-10)	
2	15 (50.0)
3	14 (46.66)
4	1 (3.33)
Total ward stay (days)	8.13±2.4
Total hospital stay (days)	10.16±2.46
Postoperative Echo	
LVEDD (cm)	5.57±0.29
LVESD (cm)	4.04±0.48
EF (%)	52.4±6.19
Mean PG (mm Hg)	11.5±1.30
Max PG (mm Hg)	23.40±2.79

AO, Aortic root; BP, bypass time; CC time, cross-clamp time; DM, diabetes mellitus; DWI, deep wound infection; EF, ejection fraction; HTN, hypertension; LVEDD, left ventricular end diastole diameter; LVESD, left ventricular end systole diameter; PG, pressure gradient; SWI, superficial wound infection. *Statistically significant.

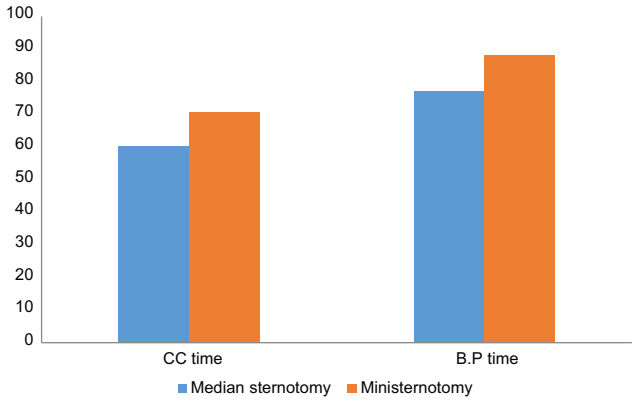

Figure 1: The comparison between the median sternotomy and ministernotomy groups regarding the cross-clamp time and the bypass time.

embolization and dissection associated with retrograde flow perfusion [16].

In our study, the rate of conversion to full median sternotomy was nil. Johnston *et al*. [7] reported 34 conversions to full sternotomy in their study, 18 of which were owing to inadequate surgical exposure. In the same context, Tabata *et al*. [17] have reported a conversion incidence rate of 2.6%; most of them were due to bleeding, ventricular dysfunction, and inadequate exposure. The need for surgical conversion was associated with higher rates of morbidity and mortality. They reported a mortality rate of 33.3%. among converted cases. However, Tabata and colleagues have used the retrograde cardioplegia technique for myocardial protection during their study. We preferred the antigrade technique to avoid unwanted complications such as coronary sinus injury during insertion of the retrograde cardioplegia catheter [17].

In our study, we had no neurological events in patients in both group. Our results were similar to other studies, showing no difference between groups regarding the development of neurological complications. Careful de-airing, the use of transesophageal echocardiography during de-airing in the ministernotomy group, and the avoidance of retrograde perfusion may all contribute to the rarity of neurological complications in our study [11–21].

Table 3: Comparison of the median sternotomy and ministernotomy groups regarding the preoperative, operative and postoperative data

	Median sternotomy group (*n*=30) [*n* (%)]	Ministernotomy group (*n*=30) [*n* (%)]	*P*
Age (years)	45.8±15.13	51.13±17.8	0218
Female sex	19 (63.33)	12 (40.0)	0.070
BMI (kg/m^2)	23.45±2.89	24.93±4.16	0.115
DM	9 (30.0)	11 (36.66)	0.583
HTN	10 (33.33)	12 (40.0)	0.592
Smoker	10 (33.33)	13 (43.33)	0.422
Preoperative Echo			
LVEDD (cm)	5.83±0.73	5.66±0.36	0.257
LVESD (cm)	4.33±0.96	4.1±0.48	0.266
EF (%)	52.33±11.01	51.56±6.47	0.742
AO (cm)	2.58±0.30	2.92±0.34	<0.001*
Pathology			
Stenosis	14 (46.66)	15 (50.0)	
Regurge	10 (33.33)	8 (26.66)	0.846
Double	6 (20.0)	7 (23.33)	
Cause of pathology			
Bicuspid	1 (3.33)	1 (3.33)	
Rheumatic	20 (66.66)	14 (46.66)	
Calcific	7 (23.33)	11 (36.66)	0.455
Degenerative	2 (6.66)	4 (13.33)	
CC time (min)	60.33±8.27	70.66±6.91	<0.001*
BP time (min)	77.0±8.46	88.±9.55	<0.001*
Prosthetic valve			
Tissue	7 (23.33)	16 (53.33)	<0.001*
Mechanical	23 (76.66)	14 (46.66)	
Size			
19	4 (13.33)	1 (3.33)	
21	6 (20.0)	10 (33.33)	0.327
23	14 (46.66)	11 (36.66)	
25	6 (20.0)	8 (26.66)	
Inotropic support			
Dobutamine	10 (33.33)	10 (33.33)	
Adrenaline	17 (56.66)	18 (60.0)	0.597
Levosimendan	1 (3.33)	0	
Duration of ventilation (h)	22.46±17.52	17.76±11.39	0.223
ICU stay (h)	64.16±29.95	55.76±32.56	0.302
Amount of bleeding (ml)	515.0±204.32	544±225.01	0.603
ICU pain degree (0-10)			
4	0	15 (50.0)	
5	12 (40.0)	13 (43.3)	<0.001*
6	17 (56.66)	2 (6.66)	
7	1 (3.33)	0	
ICU complication			
Reopening	1 (3.33)	1 (3.33)	
Heart block	2 (6.66)	2 (6.66)	0.906
Chest infection	1 (3.33)	1 (3.33)	
Renal impairment	0	1 (3.33)	
Wound infection			
SWI	2 (6.66)	1 (3.33)	0.495
DWI	1 (3.33)	0	
Ward pain degree (0-10)			
2	0	15 (50.0)	
3	3 (10.0)	14 (46.66)	<0.001*
4	21 (70.0)	1 (3.33)	
5	6 (20.0)	0	
Total ward stay (days)	7.96±2.52	6.60±1.79	0.019*
Total hospital stay (days)	10.60±3.44	8.86±3.05	0.042*
Postoperative Echo			
LVEDD (cm)	5.7±0.60	5.57±0.29	0.254
LVESD (cm)	4.25±0.87	4.04±0.48	0.251
EF (%)	52.13±9.22	52.4±6.19	0.894
Mean PG (mm Hg)	11.66±1.72	11.5±1.30	0.685
Max PG (mm Hg)	24.56±3.19	23.40±2.79	0.139

AO, aortic root; BP, bypass time; CC time, cross-clamp time; DM, diabetes mellitus; DWI, deep wound infection; EF, ejection fraction; HTN, hypertension; LVEDD, left ventricular end diastole diameter; LVESD, left ventricular end systole diameter; PG, pressure gradient; SWI, superficial wound infection. *Statistically significant.

In the current study, routine postoperative transthoracic echocardiography was done for all patients before discharge. We had no significant paravalvular leakage that required secondary intervention in all patients. Our early results were similar to other studies like Christiansen *et al.* [14], who reported no early paravalvular leakage in either of their studied groups. However, they reported minor paravalvular leakage in 18.2% of the ministernotomy AVR group and 13.0% in the conventional AVR group after 1-year follow-up. We believe that the paravalvular leakage is not related to the minimally invasive approach in particular, and further investigations are needed to illustrate this issue.

The average CCT and bypass time were statistically significantly longer in the ministernotomy group than in the conventional group, being 70.66 ± 6.91 and 60.33 ± 8.27, and 88.1 ± 9.55 and 77.0 ± 8.46, respectively. Although prolonged operative time may be associated with increased risk of systemic inflammatory response syndrome, which can lead to organ dysfunction [22,23], we did not demonstrate any clinical relevance of prolonged operative time in our patients. On the contrary, some studies have stated that increased operative time may be associated with increased rates of morbidity and mortality [12–14]. In a recent meta-analysis of 26 studies on 4586 patients, Brown *et al.* [10] have identified that the cross-clamp and bypass times were longer in the ministernotomy AVR group than in the conventional group without any clinical effect of this difference on the studied patients, and this is concordant with our findings. From another point of view, minimally invasive techniques can

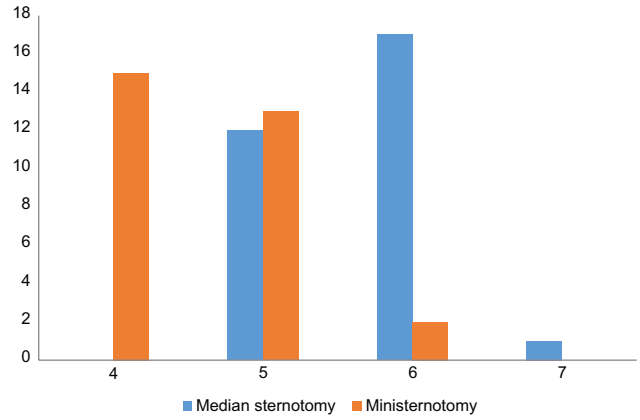

Figure 2: The comparison between the median sternotomy and ministernotomy groups regarding the ICU pain degree.

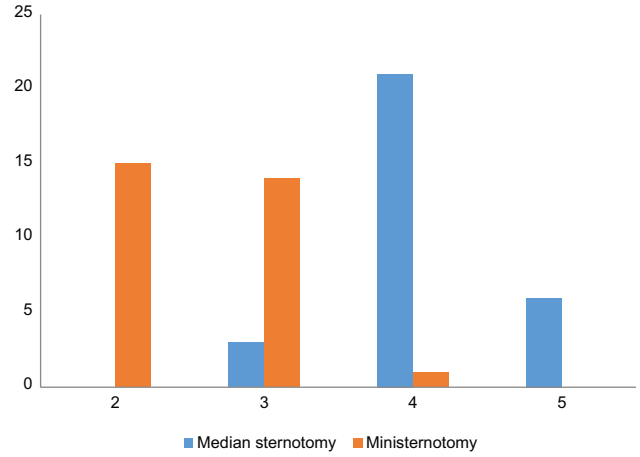

Figure 3: The comparison between the median sternotomy and ministernotomy groups regarding the ward pain degree.

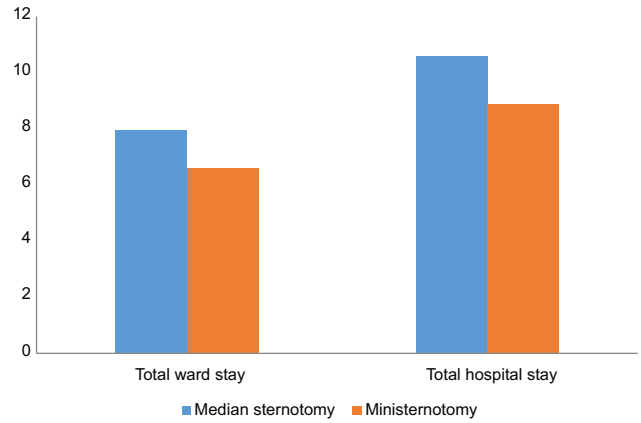

Figure 4: The comparison between the median sternotomy and ministernotomy groups regarding the total ward stay and total hospital stay.

minimize surgical trauma by reducing tissue manipulations and hence decreasing the incidence of inflammatory insult [23].

In our study, the duration of postoperative ventilation was shorter in the ministernotomy group (17.76 ± 11.39 and 22.46 ± 17.52 h, respectively). Other studies have showed similar results with the associated early relief of ventilator discomfort and the avoidance of postoperative respiratory complications [6,7,10]. Moreover, the improved sternal stability and the preservation of postoperative respiratory functions in ministernotomy group help to prevent sternal dehiscence and deep wound infections as well as increase the chance for early mobilization with early restoration of daily activity. This is important, especially in elderly patients, which are more liable for postoperative complications.

According to Santana *et al.* [24], the safety of AVR in obese patients was not affected by the surgical approach, and both ministernotomy and conventional median sternotomy were used during their study, without any affection of the surgical exposure. Moreover, the bypass time was longer in the ministernotomy group of patients (median 129 and 96 min, respectively), and this is consistent with our study.

Our analysis of postoperative pain among studied patients revealed that the ministernotomy group has suffered less pain levels than the conventional group. Pain levels were addressed through the daily consumption of analgesic medications and with the help of pain charts. Our findings were in line with the meta-analysis of Brown *et al.* [10] but opposite to the study done by Lim *et al.* [25]. The limitations for both studies were the sparse data regarding this issue, which may explain the contradictory results.

Conclusion

Aortic valve replacement through an upper ministernotomy is safe and is comparable to conventional approach in terms of early postoperative outcomes. Although our results showed increased overall operative time in ministernotomy group, yet this had no clinical effect on any of our patients. Pain levels were less severe in the ministernotomy group, favoring early postoperative ambulation and recovery to normal activity especially in elderly patients. Larger studies with end points like postoperative pain levels, postoperative recovery time, and quality of life after surgery are needed to clarify the role of minimally invasive AVR.

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Conflicts of interest

There are no conflicts of interest.

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