Journal of Medicine in Scientific Research

Volume 5 | Issue 4 Article 12

Subject Area:

Comparative study between minimally invasive right anterior minithoracotomy versus mini-upper sternotomy in isolated aortic valve replacement (early outcome)

Ashraf Abdelaziz
NHI

Hazem G. Bakr
NHI, dr_hazem212@hotmail.com

Ibrahim M. Helmi
NHI

Recommended Citation

Abdelaziz, Ashraf; Bakr, Hazem G.; and Helmi, Ibrahim M. (2023) "Comparative study between minimally invasive right anterior minithoracotomy versus mini-upper sternotomy in isolated aortic valve replacement (early outcome)," *Journal of Medicine in Scientific Research*: Vol. 5: Iss. 4, Article 12.
DOI: https://doi.org/10.4103/jmisr.jmisr_89_21

Original Article

Comparative study between minimally invasive right anterior minithoracotomy versus mini-upper sternotomy in isolated aortic valve replacement (early outcome)

Hazem G. Bakr[a], Ibrahim M. Helmi[b], Ashraf Abdelaziz[a]

Departments of [a]Cardio-Thoracic Surgery, [b]Radiology, NHI, Giza, Egypt

Abstract

Background

Minimally invasive surgical methods have lately become popular in heart surgery. Ministernotomy and minithoracotomy are the most commonly used incisions in minimally invasive aortic valve replacement. It is still debated if one incision is better than the other.

Patients and methods

A prospective comparative analysis was used to examine the outcomes of 30 patients who underwent isolated aortic valve replacement. A minimally invasive right anterior minithoracotomy approach was used in group A ($n = 15$), whereas a mini-upper sternotomy method was used in group B ($n = 15$).

Results

The results in both groups reveal no statistical difference. However, the hospital stay, ventilation time, and blood loss had better results in the right minithoracotomy group, whereas in the upper-ministernotomy group, postoperative pain had better results. In group A, blood loss was 335.3174.5, while in group B, it was 433.3 ± 169.5. In group B, postoperative pain was 1.7 ± 0.7, which is better than group A 2.5 ± 0.6. Group B had a longer total hospital stay (7.2 ± 1.3 days) than group A (5.6 ± 0.6 days). In both groups, inotropes were determined to be negligible.

Conclusion

The results of a right anterior minithoracotomy and an upper-ministernotomy approach in patients undergoing isolated Aortic valve replacement (AVR) are similar, with no notable differences. However, a right anterior minithoracotomy reduces the need for blood transfusions, assisted ventilation time, and hospital stay, while an upper-ministernotomy reduces postoperative pain. Furthermore, the cross-clamping and total operative time is highly significantly increased in right anterior minithoracotomy approach.

Keywords: Aortic valve replacement, right minithoracotomy, upper-ministernotomy are all minimally invasive procedures

Introduction

For many years, median sternotomy has been the standard procedure for all types of open heart surgery because it allows for great access to the heart. However, it is associated with a high rate of morbidity, including severe discomfort caused by rib and thoracic ligament traction. It is also linked to a higher chance of bleeding and sternal wound infection, which often demands debridement and cosmetic surgery restoration, as well as a higher risk of death [1].

Minimally invasive heart valve procedures are becoming more prevalent as new technologies and instruments become available. Several procedures and approaches have been presented, although the majority are targeted for primary valve surgery. Reoperative operations are more challenging because of the diffuse mediastinal and pericardial adhesions, but they also present an opportunity. The most helpful procedures may be

Access this article online

Quick Response Code:

Website: www.jmsr.eg.net

DOI: 10.4103/jmisr.jmisr_89_21

Correspondence to: Hazem G. Bakr, MD, Department of Cardio-Thoracic Surgery, Lecturer of Cardiac Surgery, National Heart Institute, KitKat Square, Imbaba, Cairo, Egypt.
Tel: 00201000980986;
E-mail: dr_hazem212@hotmail.com

Submitted: 20-Dec-2021 **Revised:** 24-Dec-2021 **Accepted:** 29-Dec-2021 **Published:** 11-Mar-2023

How to cite this article: Bakr HG, Helmi IM, Abdelaziz A. Comparative study between minimally invasive right anterior minithoracotomy versus mini-upper sternotomy in isolated aortic valve replacement (early outcome). J Med Sci Res 2022;5:492-7.

those that are 'minimally invasive' [2]. A large incision increases the surgeon's operative field, but it also increases morbidity and mortality. The intact chest wall, on the other hand, will maintain the integrity of the chest wall, enhancing sternal stability and allowing for quicker extubation, especially in obese patients [3].

With minimal access aortic valve surgery, the morbidity associated with the midline approach can be decreased. Despite the smaller surgical field, the aortic valve is readily visible [4,5].

Aim

The aim of this study is to compare the early outcome (6-month postoperatively) of right anterior minithoracotomy versus mini-upper sternotomy approach in patients with isolated aortic valve disease requiring aortic valve replacement according to inclusion criteria.

Patients and methods

A prospective comparative study included thirty patients who underwent aortic valve surgery in the period between March 2019 and October 2021 at the National Heart Institute. They were divided into two groups:

(1) Group A: included 15 patients who underwent aortic valve surgery through right anterior minithoracotomy via cardiopulmonary bypass using femoral artery and femoral vein cannulation.
(2) Group B: included 15 patients who underwent aortic valve surgery through J shape upper-ministernotomy using central cannulation.
    (a) The patients have been followed up for 6 months.

Inclusion criteria:
(1) Patients with isolated aortic valve disease requiring aortic valve replacement surgery.

Exclusion criteria:
(1) Patients with other valvular disease rather than isolated aortic surgery.
(2) Combined cardiac disease (valvular, congenital, or ischemic heart disease).
(3) Emergency cases.
(4) Redo cases.
(5) Patients having significant pulmonary hypertension.
(6) Preoperative comorbidities (hepatic, renal, pulmonary, etc.).

Preoperative evaluation

(1) Informed consent, history taking, and clinical examination.
(2) Routine investigations:
    (a) Routine preoperative laboratory investigations, ECG, radiological examination, echocardiography, preoperative Trans-Eosophageal-Echocardiography (TEE), coronary angiography for patients above 40 years.
    (b) Respiratory function tests.
    (c) Computed tomography aortography.

Operative procedures

Anesthesia

The patient is prepared for aortic valve replacement as usual. The procedure is carried out under general anesthesia. The patient is sedated and intubated. For single (left) lung ventilation, a twin-lumen endotracheal tube can be utilized in group A. A probe for transesophageal echocardiography is inserted.

In group A, the patients are positioned supine and an air sack is put under the right scapulae to allow the surgeon to shift the patient's right chest upward or lower throughout the surgery as needed for a greater working field exposure. The patient's anterior and right lateral chest walls, as well as both groin areas, are draped.

Surgical approach

The surgery is carried out in group A via an incision in the right second or third intercostal region. The medial angle of the incision is positioned lateral to the right internal mammary artery, which is 1.5–2 cm laterally to the sternal border, and lateral angle considering the other mean length of incision of 6–10 cm, which varies in various patients.

The pericardium is incised, and stay sutures are put on the incised pericardium's lateral edge. The workplace environment is well-lit.

Preparation is started on the groin. Both femoral vein and femoral artery were exposed and cannulated guided by TEE.

The intervention will proceed as usual. The cannula for the aortic root has been inserted. To ensure a bloodless field, a venting cannula is inserted into the right superior pulmonary vein.

The cardioplegia is administrated in a conventional manner.

Myocardial protection is originally provided via a cardioplegia is administered as a single dose/shot of crystalloid solution (Custodiol) into both coronary ostia antegradely. Cross-clamping is via a straight cross-clamp through the incision.

In group B: upper J-shaped incision into the third or fourth intercostal space using central aortocaval cannulation.

Data recorded

(1) Operative time.
(2) Time of aortic cross-clamp and extracorporeal circulation.
(3) Demographic data and clinical characteristics.
(4) Inotropes.
(5) Echocardiographic finding.
(6) Pulmonary function test.

Postoperative data

(1) ICU stay, ventilation, inotropic agents when indicated and postoperative echo.

Judgment criteria

(1) The main judgment criteria will be:
    (a) Vital signs (blood pressure, temperature, pulse, urine output, and oxygen saturation).

(b) ECG first day, 48 h, and end of the first week.
(c) Echocardiography.
(d) Pulmonary function test.

The postoperative echo

An echo was done before discharge to the monitor:
(1) LVEDD and LVESD.
(2) Postoperative EF.

Ethical considerations

The institutional committee's ethical criteria were followed during all proceedings. Ethics Committee approved the study. Approved in ethical committee on 10th of February, 2019.

Results

This study was to compare the procedure and early postoperative outcome (6-month postoperatively) of the mini-upper sternotomy approach versus the minimally invasive approach through right anterior minithoracotomy technique.

Demographic data

Table 1.

Preoperative data analysis

Tables 2 and 3.

Operative analysis

Tables 4–6.

Postoperative data analysis

Inotropes were found to be nonsignificant in both groups Tables 7–10.

Discussion

Despite an increase in the number of elderly patients and those with serious comorbidities, AVR mortality and postoperative complications have decreased dramatically in the previous decade [6]. Minimally invasive surgery has become a safe and successful treatment option with increased patient satisfaction as new technologies, surgical, and anesthetic techniques have improved [7]. The most commonly used incisions in minimally invasive aortic valve replacement are ministernotomy and minithoracotomy [8].

Minimally invasive AVR has been shown to lessen postoperative complications, resulting in a faster recovery, a shorter hospital stay, less discomfort, better cosmetic results, and the utilization of fewer hospital resources [5]. In small randomized trials, Bonacchi *et al*. [9] found that minimally invasive AVR reduced blood transfusions, mechanical ventilation, and hospital stay.

Our findings demonstrate that right anterior minithoracotomy AVR is a safe and repeatable procedure with low postoperative mortality and morbidity, as well as good midterm survival. Patients who had AVR by right anterior minithoracotomy had a lower rate of postoperative blood transfusions, as well as a shorter breathing duration and postoperative length of stay, than those who had AVR using an upper-ministernotomy. However, the upper-ministernotomy technique had better results than the right anterior ministernotomy strategy in terms of postoperative pain; however, the difference was not significant. Furthermore, with the right anterior minithoracotomy method, cross-clamping and total surgical time are greatly increased.

Despite the fact that the cross-clamp and cardiopulmonary bypass times were longer, those who received any minimally

Table 1: Age and sex of both groups

	Group A Mean±SD	Group B Mean±SD	*P*
Age (years)	53.88±17.80	51.36±18.05	NS
Male	6	9	NS
Females	9	6	NS

P less than 0.05 is considered significant.

Table 2: Preoperative echocardiography in both groups

Pre echocardiography	Group A Mean±SD	Group B Mean±SD	*P*
EF%	TxDone	55.44±13.67	NS
EDD	5.30.56	5.59±0.61	NS
ESD	3.580,68	3.45±0.65	NS
Left atrial dimension	4.3±0.7	3.7±0.9	NS
Pulmonary artery pressure	42.7±7.7	38.6±7.7	NS

EDD, end-diastolic dimension; EF%, ejection fraction %; ESD, end-systolic dimension. *P* less than 0.05 is considered significant.

Table 3: Preoperative NYHA classification

Preoperative NYHA classification	Group A	Group B	*P*
I	3	3	NS
II	8	7	NS
III	4	5	NS
IV	0	0	NS

Table 4: Difference in total operative time, cross-clamp, and total bypass time in both groups

	Group A Mean±SD	Group B Mean±SD	*P*	
Cross-clamp (min)	73.3±28.5	55.7±9.5	0.032*	Significant
Total bypass time (min)	115.7±30.2	66.7±15.7	<0.001*	Highly significant
Total operation time (mean±SD) (min)	249±22.7	213±28.4	0.020*	Significant

*Statistically significant, *P* less than 0.05 is considered significant.

Table 5: Patients requiring inotropic, DC shock during weaning from cardiopulmonary bypass

	Group A [*n* (%)]	Group B [*n* (%)]	*P*
DC shock	5 (33.3)	4 (26.6)	NS
Inotropic support	10 (60)	11 (73.3)	NS

P less than 0.05 is considered significant. NS, non significant.

Table 6: Operative and postoperative parameters in both groups that show the upper hand of minimally invasive surgery

	Group A Mean±SD	Group B Mean±SD	*P*
Length of skin incision (cm)	7.1±2.4	9.1±3.2	NS
Ventilation (h)	2.6±0.5	3.3±2.2	NS
Blood loss (ml)	335.3174.5	433.3±169.5	NS
Blood transfusion (U)	0.7±0.8	1±0.8	NS
Postoperative pain			
Within 5 days	2.5±0.6	1.7±0.7	NS
Total hospital stay (day)	5.6±0.6	7.2±1.3	NS

P less than 0.05 is considered significant. NS, non significant.

Table 7: Inotropic need in both groups

	Group A	Group B	*P*
Inotropes	7	5	NS

P less than 0.05 is considered significant. NS, non significant.

Table 8: Postoperative complications of both approaches

Postoperative complications	Group A [*n* (%)]	Group B [*n* (%)]	*P*
No complications	11 (73)	10 (66.6)	NS
Arrhythmias	2 (13.3)	1 (6.7)	NS
ARDS	1 (6.7)	2 (13.3)	NS
Superficial wound infection	1 (6.7)	2 (13.3)	NS
Mortality	0	0	NS

There was no statistical significant difference as regards postoperative complications in both groups. NS, non significant.

Table 9: Postoperative echocardiograph in both groups after 3 months

Postoperative echocardiograph	Group A Mean±SD	Group B Mean±SD	*P*
EF%	55.8±8.8	53.54±9.82	P
EDD (cm)	5.210.70	5.3±0.77	NS
ESD (cm)	3.60.749	3.84±0.71	NS
Left atrial dimension	4.1±0.5	3.5±0.7	NS
Pulmonary artery pressure	37.6±7.3	33.2±3.6	NS

EDD, end-diastolic dimension; EF%, ejection fraction %; ESD, end-systolic dimension; NS, non significant. *P* value less than 0.05 is considered significant.

invasive procedure benefited in terms of perioperative mortality, ICU and hospital stay, and ventilation time, according to a meta-analysis of 4667 patients undergoing isolated AVR [10]. Brown *et al*. [11] recently confirmed these effects after conducting a thorough review and meta-analysis of 26 trials involving 4586 individuals who received ministernotomy or a conventional technique. According to the data, ministernotomy was associated with shorter ventilation times, critical care unit and hospital stays, and lower blood loss within 24 h [11].

Despite these promising results, the majority of these investigations have focused on ministernotomy. Only a few trials have looked into the possible benefits of minimally invasive AVR using the right anterior minithoracotomy approach. Several case series have documented low incidence of atrial fibrillation (AF) and favorable outcomes in terms of mortality and postoperative complications, blood transfusions, mechanical breathing, and hospital stay after surgery [7].

In a propensity score matched analysis, Ruttmann *et al*. [12] found a longer postoperative breathing time and a trend toward a higher rate of renal failure in patients undergoing Right (RT) minithoracotomy, but no difference in early postoperative outcomes. The lack of benefits of minimally invasive AVR was most likely related to the older individuals in the matched minimally invasive AVR group. It is generally understood that becoming older raises the risk of postoperative AF, as well as renal and pulmonary complications [12].

In a larger and good propensity matched cohort, Sharony *et al*. [13] found that patients who underwent minimally invasive AVR via RT minithoracotomy (90% of total) or ministernotomy had a shorter postoperative length of stay and a higher proportion of patients discharged directly home than those who underwent conventional sternotomy.

According to our findings, patients in the right ministernotomy group were extubated sooner and required fewer blood transfusions. The smaller incision, preservation of the sternum, and preservation of the costal cartilages would all help with breathing. Minimally invasive AVR was connected to a lower rate of AF after AVR, according to De Smet *et al.* [14]. Reduced dissection of other areas may further reduce the risk of hemorrhage and blood transfusions, albeit claimed that no differences in chest reopening were observed.

Our results regarding the length of operative time were different from that of the study of Olds *et al.* [15]. The study included 503 patients which claimed that the minithoracotomy approach showed decreased operative times besides other benefits in decreasing lengths of stay, decreased incidence of prolonged ventilator time, and a trend toward lower mortality when compared with ministernotomy and conventional sternotomy.

Our findings are consistent with those of Mourad and Abd Al Jawad [16], who conducted a retrospective review of 260 patients who underwent mini-AVR, with 132 patients undergoing ministernotomy and 128 patients undergoing minithoracotomy. The Mini-Sternotomy (MS) technique had considerably shorter cross-clamp and total bypass times than the MT strategy (63.6116.115 vs. 70.7533.274 min, $P = 0.028$, and 91.9026.365 vs. 112.2451.634 min, $P = 0.001$, respectively). The wounds in the minithoracotomy group were significantly shorter (5.1 0.6 vs. 8.480.344 cm, $P = 0.001$). In the ICU, after hospital discharge, and after 30 days at the outpatient clinic, the ministernotomy group

Table 10: Postoperative echocardiograph in both groups after 6 months

Postoperative echocardiograph	Group A Mean±SD	Group B Mean±SD	*P*
EF%	57.8±6.8	56.44±8.37	NS
EDD (cm)	4.510.30	5.3±0.39	NS
ESD (cm)	3.30.5	3.5±0.7	NS
Left atrial dimension	4.0±0.2	3.6±0.77	NS
Pulmonary artery pressure	36.6±6.3	32.3±4.56	NS

EDD, end-diastolic dimension; EF%, ejection fraction %; ESD, end-systolic dimension. *P* less than 0.05 is considered significant.

had substantially lower postoperative pain levels than the MT group (4.461.23 vs. 5.231.12, $P = 0.001$, 1.60.84 vs. 1.830.72, $P = 0.019$, and 1.280.67 vs. 1.470.53, $P = 0.012$, respectively) [16].

Miceli *et al*. [17] were the first to compare RT and MS in the context of low-access AVR (mini-AVR). They compared the baseline characteristics of the two groups in an unmatched nonrandomized comparison of 406 consecutive patients. Although there was no difference in in-hospital mortality between the two approaches (RT = 1.2%, MS = 1.3%; $P = 1$), the authors discovered that Right (RT) was associated with lower postoperative morbidity in terms of reduced ventilation times, shorter stays in the ICU and ward, and lower rates of postoperative AF.

Fattouch *et al.* [18] compared AVR via MS or RT in 1130 individuals in a large multicenter retrospective study. For the major end point of 30-day mortality, the authors discovered no significant differences between the groups. In comparison to MS, they report considerably higher rates of reoperation for bleeding with RT [21 (8%) vs. 30 (3.8%); $P = 0.006$]. When analyzing both of these findings, it is important to remember that the MS group was a higher-risk group of patients, with a considerably higher BMI, EuroSCORE, and proportion of New York Heart Association Grade IIIa and IV patients [18].

In 297 patients, Shen *et al.* [19] conducted a nonrandomized comparison. The MS procedure used a J-incision and either central or femoral Cardio Pulmonary Bypass (CPB), whereas the RT procedure used peripheral bypass. Shen *et al*. [19] found no significant difference in in-hospital mortality between RT and MS (3.0 vs. 0.6%), as in prior studies ($P = 0.175$). In the RT group, they also had higher CPB periods (92.27 vs. 76.18 min; $P = 0.001$). However, they discovered that RT was linked to a shorter hospital stay (median: 5 vs. 9 days; $P = 0.001$) and lower transfusion rates (20.4% vs. 39.4%; $P = 0.001$). Shen *et al.* [19] make no mention of reoperation rates for bleeding in this cohort.

In 160 propensity-matched pairs, Semsroth *et al.* [20] conducted a single-center investigation of MS versus RT for AVR. They discovered no statistically significant difference in 90-day mortality using either technique. The RT group had a greater mortality rate ($n = 6$, 3.8%) than the MS group ($n = 2$, 1.3%), although the difference was not statistically significant ($P = 0.16$). Increased CPB (137 vs. 113 min; $P = 0.0001$) and cross-clamp times (93 vs. 75 min; $P = 0.001$) as well as higher rates of conversion to full sternotomy (13.1 vs. 4.4%; $P = 0.004$) and the need for a second cross-clamp period (8.8 vs. 1.3%; $P = 0.003$) were associated with the RT approach [20].

Sutureless devices are expected to reduce operational times, making this treatment even simpler and more consistent. Because of the outstanding postoperative outcomes associated with the least invasive approach, the RT minithoracotomy and upper-ministernotomy technique may be considered an option to TAVI for high-risk patients [21]. In a retrospective study, Zierer *et al*. [22] found that patients who underwent TAVI and minimally invasive AVR procedures had similar early mortality and morbidity.

The PARTNER trial [23] discovered that transcatheter AVR is comparable to conventional surgery in terms of early mortality and 1-year survival. TAVI procedures, on the other hand, have been related to an increased risk of vascular complications, including embolic stroke and paravalvular leak. In our series, there were no vascular issues, and the lower risk of postoperative stroke and paravalvular leaking makes right anterior minithoracotomy a safe and viable option to TAVI [23].

Finally, right anterior minithoracotomy patients required more time for cardiopulmonary bypass and aortic cross-clamping than those who received upper-ministernotomy. This was a limitation of our method, meaning that exposing and implanting the prosthetic valves is more challenging than the conventional way.

Conclusion and Recommendation

In patients undergoing isolated AVR, a right anterior minithoracotomy and upper-ministernotomy approaches have similar results without significant difference. However, right anterior minithoracotomy lowers the requirement for blood transfusions, postoperative ventilation time, and hospital stay, while the upper-ministernotomy approach lowers postoperative pain. Our findings suggest that cardiac surgery is still debatable in terms of cost-effectiveness, making econometric analysis a critical component of any future assessment of innovative cardiovascular therapy. Additional multicenter investigations are needed to corroborate our findings.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Fraziera BL, Derricka MJ, Purewala SS, Sowkaa LR, Johnac S. Minimally invasive aortic valve replacement Eur J Cardiothorac Surg

1998; 14 (Suppl. 1):S122–S125.
2. Glower DD, Teng L, Desai B. Aortic valve replacement through right minithoracotomy in 306 consecutive patients. Innovations 2010; 5:326–330.
3. Glauber M, Miceli A, Bevilacqua S, Farneti PA. Minimally invasive aortic valve replacement via right anterior minithoracotomy: early outcomes and mid term follow-up. J Thorac Cardiovasc Surg 2011; 142:1557–1559.
4. Malaisrie SC, McCarthy PM, McGee EC, Lee R, Rigolin VH, Davidson CJ. Contemporary perioperative results of isolated aortic valve replacement for aortic stenosis. Ann Thorac Surg 2010; 89:751–757.
5. El-Hameed Mohammed MA, Abd El-Aziz AS, Saleh RH. Right anterolateral minithoracotomy versus median sternotomy in mitral valve replacement. Med J Cairo Univ 2018; 86:4039–4045.
6. Thosani R, Joshi P, Doshi C. Minimally invasive combined aortic and mitral valve replacement heart. Lung Cir 2011; 20:4.
7. Plass A, Scheffel H, Alkadi H, Kaufmann P, Genoni M, Falk V. Aortic valve replacement through a minimally invasive approach; preoperative planning, surgical technique and outcome. Ann Thorac Surg 2009; 88:1851–1856.
8. Balmforth D, Harky A, Lall K, Uppal R. Is ministernotomy superior to right anterior minithoracotomy in minimally invasive aortic valve replacement?. Interact Cardiovasc Thorac Surg 2017; 25:818–821.
9. Bonacchi M, Profti E, Giunti G, Frati G, Sani G. Does ministernotomy improve postoperative outcome in aortic valve operation?; a prospective randomized study. Ann Thorac Surg 2002; 73:460–466.
10. Alassal M, Saffan M, Mofreh B, AbdEl-Shafi S, Rezk M, Fawzy E, *et al*. Minimally invasive aortic valve replacement via right minithoracotomy versus conventional full median sternotomy: tertiary center experience. Am J Cardiovasc Thorac Surg 2018; 3:1–7.
11. Brown JM, O'Brien SM, Wu C, Sikora JA, Griffith BP, Gammie JS. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: change in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. J Thorac Cardiovasc Surg 2009; 137:82–90.
12. Ruttmann E, Gilhofer TS, Ulmer H, Chevtchik O, Kocher A, Schistek R. Propensity score-matched analysis of aortic valve replacement by minithoracotomy. J Heart Valve Dis 2010; 19:606–614.
13. Sharony R, Grossi EA, Saunders PC, Schwartz CF, Ribakove GH, Baumann G. Propensity score analysis of a six year experience with minimally invasive isolated aortic valve replacement. J Heart Valve Dis 2004; 13:887–893.
14. De Smet JM, Rondelet B, Jansens JL, Antoine M, De Canniere D, Le Clerc JL. Assessment based on euroSCORE of ministernotomy for aortic valve replacement. Asian Cardiovasc Thorac Ann 2004; 12:53–57.
15. Olds A, Saadat S, Azzolini A, Dombrovskiy V, Odroniec K, Lemaire A, *et al*. Improved operative and recovery times with mini-thoracotomy aortic valve replacement. J Cardiothorac Surg 2019; 14:91.
16. Mourad F, Abd Al Jawad M. Mini sternotomy and mini thoracotomy for aortic valve replacement: is there a difference?. Heart Surg Forum 2021; 24:E855–E859.
17. Miceli A, Murzi M, Gilmanov D, Fuga R, Ferrarini M, Solinas M. Minimally invasive aortic valve replacement using right minithoracotomy is associated with better outcomes than ministernotomy. J Thorac Cardiovasc Surg 2014; 148:133–137.
18. Fattouch K, Moscarelli M, Del Giglio M, Albertini A, Comoglio C, Coppola R. Mini-sternotomy versus mini-thoracotomy: a series of 1130 patients. Interact Cardiovasc Thorac Surg 2016; 23:253–258.
19. Shen JQ, Wei L, Xia LM, Lai H, Sun YX, Sun XN. Comparison of anterolateral minithoracotomy versus partial upper hemisternotomy in aortic valve replacement. Zhonghua Wai Ke Za Zhi 2016; 54:601–604.
20. Semsroth S, Matteucci-Gothe R, Heinz A, Dal Capello T, Kilo J, Muller L. Comparison of anterolateral minithoracotomy versus partial upper hemisternotomy in aortic valve replacement. Ann Thorac Surg 2015; 100:868–873.
21. Schitto JD, Mokashi SA, Cohn LH. Minimally invasive valve surgery. J Am Coll Cardiol 2010; 56:455–462.
22. Zierer A, Wimmer-Greinecker G, Martens S, Moritz A, Doss M. Is transapical aortic valve implantation really less invasive than minimally invasive aortic valve replacement?. J Thorac Cardiovasc Surg 2009; 138:1067–1072.
23. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG. Transcatheter versus surgical aortic-valve replacement in high-risk patients. N Engl J Med 2011; 364:2187–2198.