Original article

eISSN 2799-8010
J Yeungnam Med Sci 2024;41(3):213-219
https://doi.org/10.12701/jyms.2024.00290

JYMS
JOURNAL OF YEUNGNAM MEDICAL SCIENCE

Aortic valve replacement through right anterior mini-thoracotomy in patients with chronic severe aortic regurgitation: a retrospective single-center study

Eun Yeung Jung, Ji Eun Im, Ho-Ki Min, Seok Soo Lee

Department of Thoracic and Cardiovascular Surgery, Yeungnam University College of Medicine, Daegu, Korea

Background: Aortic valve replacement (AVR) has recently been performed at many centers using a minimally invasive approach to reduce postoperative mortality, morbidity, and pain. Most previous reports on minimally invasive AVR (MiAVR) have mainly focused on aortic stenosis, and those exclusively dealing with aortic regurgitation (AR) are few. The purpose of this study was to investigate early surgical results and review our experience with patients with chronic severe AR who underwent AVR via right anterior mini-thoracotomy (RAT).

Methods: Data were retrospectively collected in this single-center study. Eight patients who underwent RAT AVR between January 2020 and January 2024 were enrolled. Short-term outcomes, including the length of hospital stay, in-hospital mortality, postoperative complications, and echocardiographic data, were analyzed.

Results: No in-hospital mortalities were observed. Postoperative atrial fibrillation occurred temporarily in three patients (37.5%). However, none required permanent pacemaker implantation or renal replacement therapy. The median values of ventilator time, length of intensive care unit stay, and hospital stay were 17 hours, 34.5 hours, and 9 days, respectively. Preoperative and postoperative measurements of left ventricular ejection fraction were similar. However, the left ventricular end systolic and diastolic diameters significantly decreased postoperatively from 42 mm to 35.5 mm ($p=0.018$) and 63 mm to 51 mm ($p=0.012$), respectively.

Conclusion: MiAVR via RAT is a safe and reproducible procedure with acceptable morbidity and complication rates in patients with chronic severe AR. Despite some limitations such as a narrow surgical field and demanding learning curve, MiAVR is a competent method for AR.

Keywords: Aortic valve insufficiency; Aortic valve replacement; Minimally invasive surgical procedures

Introduction

Aortic regurgitation (AR) and moderate-to-severe AR occur in approximately 4.9% and 0.5% of the population, respectively. AR typically peaks in the fourth to sixth decades of life [1]. Chronic AR is characterized by left ventricular (LV) volume overload that leads to LV compensatory dilatation and hypertrophy [2]. Current guidelines recommend aortic valve replacement (AVR) or aortic valve repair in patients with symptomatic severe AR or asymptomatic severe AR with the following: (1) a LV ejection fraction (LVEF) ≤55%, (2) an LVEF >55% and a LV end systolic diameter (LVESD) >50 mm (LVESD index >25 mm/m^2), and (3) a progressive decrease in LVEF to 55% to 60% or an increase in LV end

Received: March 20, 2024 • **Revised:** May 23, 2024 • **Accepted:** May 25, 2024 • **Published online:** June 12, 2024
Corresponding author: Ho-Ki Min, MD
Department of Thoracic and Cardiovascular Surgery, Yeungnam University College of Medicine, 170 Hyeonchung-ro, Nam-gu, Daegu 42415, Korea
Tel: +82-53-620-3880 • Fax: +82-53-626-8660 • E-mail: minhoki@naver.com

diastolic diameter (LVEDD) to >65 mm on at least three serial measurements [3]. Although this is the era of transcatheter AVR (TAVR) for patients with aortic stenosis (AS), surgery is still considered the gold standard for AR. Full sternotomy was the conventional approach for surgical AVR. However, AVR has recently been performed in many cases using a minimally invasive approach to reduce postoperative mortality, morbidity, and pain. This approach also facilitates faster recovery, shorter hospital stays, and better cosmetic results than conventional AVR [4]. Most previous reports on minimally invasive AVR (MiAVR) have mainly focused on AS, with only a limited number of papers exclusively addressing AR. Thus, this study aimed to investigate early surgical outcomes and review our experience with patients with chronic severe AR who underwent AVR via right anterior mini-thoracotomy (RAT).

Methods

Ethical statements: This study was approved by the Institutional Review Board (IRB) of Yeungnam University Hospital (IRB No: 2024-03-014). The requirement for informed consent was waived due to the retrospective nature of the study.

1. Patient selection

Our indications for RAT AVR in patients with severe chronic AR were as follows: (1) patients with the abovementioned surgical indications [2,3,5]; (2) suitability for RAT surgery, indicated by an ascending aorta located ≥50% rightward of the right sternal border at the level of the pulmonary artery bifurcation and an alpha angle of ≥45° [6]; and (3) absence of acute lung disease.

The following cases were excluded from this study: (1) those unsuitable for MiAVR [6]; (2) those with surgically repairable AR [7-9]; (3) those requiring root replacement or ascending aorta replacement; (4) those accompanied by other valvular diseases that needed surgical interventions; (5) those who previously underwent AVR (redo surgery); and (6) those with acute AR, including infective endocarditis.

Between January 2020 and January 2024, 102 consecutive patients with aortic insufficiency underwent surgery at our hospital. Of these patients, 45 had severe AR, 16 of whom underwent RAT AVR. After excluding those who underwent reoperation and those who had endocarditis or other concomitant valvular diseases, eight patients were included in this study. All the surgical procedures were performed by a single surgeon.

2. Data collection

Data were retrospectively collected from patients with chronic severe AR who underwent AVR using the RAT approach at our institution between January 2020 and January 2024. Data were obtained from an institutional database that included detailed information on patient demographics, baseline clinical characteristics, severity of symptoms according to the New York Heart Association (NYHA) classification, and laboratory and hemodynamic parameters. Coronary angiography, echocardiography, and chest computed tomography were routinely performed as part of the preoperative workup. This was performed to determine the site of arterial cannulation (axillary or femoral artery cannulation for MiAVR), assess the adequacy of direct cardioplegia delivery for myocardial protection, and ascertain the patient's eligibility for MiAVR via RAT.

3. Surgical procedure

The surgical procedures are described in detail in our previous report [10]. Briefly, cardiopulmonary bypass (CPB) was performed in all patients using peripheral arterial cannulation and bicaval venous cannulation without central cannulation. Femoral arterial cannulation was our preferred choice. However, if preoperative workup, chest, or abdominal computed tomography suggested peripheral vascular disease in the lower extremities, or severe atherosclerotic aortic disease was evident on transesophageal echocardiography (TEE), we opted for right axillary artery cannulation via a right infraclavicular approach using a 5-cm transverse incision. This approach allowed for antegrade arterial perfusion and reduced the risk of embolic events. Femoral artery cannulation was performed in three patients, while right axillary artery cannulation was performed in five patients. In all patients, cardioplegia was delivered directly to the coronary ostia immediately after aortotomy to ensure myocardial protection. None of the patients required a sternotomy. Prior to wound closure, drains were placed in the pericardium and pleura. All the surgeries were performed uneventfully.

All patients received a single dose of 20 mL/kg of histidine-tryptophan-ketoglutarate cardioplegia solution at a temperature of 4°C to 5°C for 6 to 8 minutes. If the aortic cross-clamp (ACC) time exceeded 120 minutes or electrical activity was detected early, the histidine-tryptophan-ketoglutarate cardioplegia solution was readministered at a dose of 10 mL/kg. One patient underwent additional patch repair using bovine pericardium due to an aneurysmal change protruding from the subannulus of the right coronary cusp toward the interventricular septum.

4. Statistical analysis

IBM SPSS ver. 27.0 (IBM Corp., Armonk, NY, USA) was used for data storage and analysis, with $p < 0.05$ as the criterion for significance. Because normality was not satisfied, nonparametric ap-

proaches were used in all the analyses. The Wilcoxon signed-rank test was used to compare the outcomes before and after the intervention. The Mann-Whitney U test was performed to compare outcomes by group. Continuous variables are expressed as median (interquartile range) or mean ± standard deviation. Categorical variables are expressed as number (percentage).

Results

1. Baseline characteristics

The median age of the patients was 65 years (range, 54–82 years) (Table 1). The median Society of Thoracic Surgeons risk score was 1.24% (range, 0.81%–2.04%). Of the eight patients, five (62.5%) had hypertension, one (12.5%) had diabetes mellitus, and three (37.5%) had hyperlipidemia. Three patients (37.5%) had a bicuspid aortic valve. None of the patients had previous atrial fibrillation (AF). The median LVEF was 56% (range, 42%–72%). The median LVESD was 42 mm (range, 39–51 mm) and the median LVEDD was 63 mm (range, 55–66 mm). Three patients (37.5%) were asymptomatic with severe AR (NYHA class I), while five (62.5%) were symptomatic (NYHA class II or greater). Among the patients designated NYHA class I, two had progressive AR, leading to the decision for surgical treatment, and the other exhibited progressive LV dilatation (LVEDD > 65 mm), which warranted surgical intervention [2,3,5,6]. The preoperative characteristics are summarized in Table 1.

2. Intraoperative characteristics

All the patients underwent elective surgery. Among them, bioprosthetic valves were used in six patients (75.0%), including three rapid-deployment (RD) valves (Edwards INTUITY Elite valve, Edwards Lifesciences, Irvine, CA, USA). A mechanical valve was used in two patients (25.0%) aged < 60 years. A 23-mm valve was used in three patients (37.5%), while a 25-mm valve was used in five (62.5%). In the RD-AVR group, the median operating, ACC, and CPB times were 285 minutes (range, 275–290 minutes), 102 minutes (range, 90–104 minutes), and 133 minutes (range, 121–140 minutes), respectively. Conversely, in the non-RD-AVR group, the procedure took relatively longer, with median operating, ACC, and CPB times of 340 minutes (range, 250–390 minutes), 127 minutes (range, 98–188 minutes), and 195 minutes (range, 135–235 minutes), respectively (Table 2). The median ACC and CPB times for patients who underwent isolated AVR were 104 minutes and 140 minutes, respectively, excluding patient number three who underwent concurrent procedures (Table 3).

3. Clinical outcomes

No operative or in-hospital mortalities were observed. Postoperative AF temporally occurred in three patients (37.5%), one in the

Table 1. Baseline characteristics of patients

Characteristics	Data
No. of patients	8
Age (yr)[a]	65
Female sex	2 (25.0)
Hypertension	5 (62.5)
Diabetes mellitus	1 (12.5)
Hyperlipidemia	3 (37.5)
Coronary arterial disease	0 (0)
Chronic kidney disease	0 (0)
COPD	0 (0)
Atrial fibrillation	0 (0)
Ejection fraction (%)[a]	56
Bicuspid aortic valve	3 (37.5)
LVESD (mm)[a]	42
LVEDD (mm)[a]	63
NYHA class	
I	3 (37.5)
II	4 (50.0)
III	1 (12.5)
STS score[a]	1.24

Values are presented as number only, median value[a], or number (%).
COPD, chronic obstructive pulmonary disease; LVESD, left ventricular end systolic diameter; LVEDD, left ventricular end diastolic diameter; NYHA, New York Heart Association; STS, Society of Thoracic Surgeons.

Table 2. Intraoperative data

Variable	Data
No. of patients (RAT AVR)	8
Concomitant cardiac surgery	1 (12.5)
Type of prosthesis	
Bioprosthetic	6 (75.0)
Rapid deployment	3 (37.5)
Mechanical	2 (25.0)
Valve size (mm)	
23	3 (37.5)
25	5 (62.5)
Arterial cannulation	
Axillary	5 (62.5)
Femoral	3 (37.5)
Surgical time (min), RD:NRD	
CPB time	133:195
ACC time	102:127
Operation time	285:340

Values are presented as number only or number (%) unless otherwise specified.
RAT AVR, right anterior mini-thoracotomy aortic valve replacement; RD, rapid-deployment aortic valve replacement group; NRD, non-rapid-deployment aortic valve replacement group; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp.

Table 3. Patient data

Patient No.	Age (yr)	Sex	LVEF (n)		LVESD (n)		LVEDD (n)		ACC (n)	CPB (n)
			Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative		
1	82	Female	50	52	39	36	55	51	90	121
2	81	Male	59	68	45	33	66	46	104	133
3	64	Male	53	54	43	34	62	49	188	235
4	64	Male	72	65	37	35	64	55	102	140
5	66	Female	49	57	47	31	66	45	127	156
6	54	Male	60	48	41	39	61	55	149	195
7	54	Male	62	48	40	36	61	51	98	135
8	67	Male	42	45	51	51	64	63	127	206
Mean ± SD	66.5		55.9 ± 8.7	54.6 ± 7.7	42.9 ± 4.3	36.9 ± 5.8	62.4 ± 3.4	51.9 ± 5.4	123.1 ± 30.5	165.1 ± 38.8
Median	65.0		56.0	53.0	42.0	35.5	63.0	51.0	115.5	148.0

LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; LVEDD, left ventricular end diastolic diameter; ACC, aortic cross-clamp time; CPB, cardiopulmonary bypass time; SD, standard deviation.

RD-AVR group and two in the non-RD-AVR group. These patients achieved sinus conversion before discharge with medication alone, and none of them required permanent pacemaker implantation. We did not observe any wound problems or cases of stroke or postoperative acute renal failure requiring continuous renal replacement therapy. In the RD-AVR and non-RD-AVR groups, the median ventilation times were 16 hours (range, 8–17 hours) and 17 hours (range, 15–22 hours), respectively. The length of intensive care unit (ICU) stay was 25 hours (range, 25–45 hours) in the RD group and 44 hours (range, 24–48 hours) in the non-RD group. The length of hospital stay was 9 days (range, 8–18 days) in the RD group and 9 days (range, 7–13 days) in the non-RD group. After surgery, the median total drainage volume in the first 24 hours was 250 mL. Revision surgery was not required because of bleeding. Drainage catheters were removed within 2 to 3 days after surgery in both groups (Table 3).

A follow-up echocardiography was performed before discharge. Perioperative echocardiographic variables are shown in Table 4. No patient presented with paravalvular leakage. The median postoperative mean systolic pressure gradient was 10.55 mmHg. There was no substantial difference in LVEF between the preoperative and postoperative results, with a slight reduction from 56% to 53% ($p = 0.889$). Both LVESD and LVEDD decreased significantly after surgery. The LVESD decreased from 42 mm to 35.5 mm ($p = 0.018$) and the LVEDD decreased from 63 mm to 51 mm ($p = 0.012$). Detailed data for each patient are presented in Table 5.

Table 4. Clinical outcomes

Variable	RD (n = 3)	NRD (n = 5)
Ventilator time (hr)[a]	16	17
Length of ICU stay (hr)[a]	25	44
Length of hospital stay (day)[a]	9	9
In-hospital mortality (%)[a]	0	0
Postoperative arterial fibrillation	1 (33.3)	2 (40.0)
Device technical success	3 (100)	5 (100)
Drainage for 24 hr after surgery (mL)[a]	400	340

Values are presented as median value[a] or number (%).
Reoperation, postoperative acute kidney injury, wound infection, femoral wound problems, stroke, pacemaker implantation, and paravalvular leakage were not observed in either group.
RD, rapid-deployment aortic valve replacement group; NRD, non-rapid-deployment aortic valve replacement group; ICU, intensive care unit.

Table 5. Preoperative and postoperative echocardiographic variables

Variable	Preoperative	Postoperative	*p*-value[a]
LVEF (%)	56.0	53.0	0.889
LVESD (mm)	42.0	35.5	0.018
LVEDD (mm)	63.0	51.0	0.012
MSPG (mmHg)	NA	10.6	NA

All values are medians.
LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; LVEDD, left ventricular end diastolic diameter; MSPG, mean systolic pressure gradient; NA, not applicable.
[a]Wilcoxon signed-rank test.

4. Comparative data

Comparative data between patients who underwent isolated AVR via sternotomy at our hospital during the same period (between January 2020 and January 2024), encompassing both AS and AR (n = 5), and a group of patients who underwent isolated AVR via the RAT approach were compared (Table 6). Isolated AVR via sternotomy was performed primarily in patients with preexisting lung disease or those deemed unsuitable for the RAT approach. As shown in Table 6, no significant differences were observed in the parameters between the two groups, except for the length of hospital stay. The mean length of hospital stay in the RAT AVR group was 9.7 days, which was significantly lower than that in the group undergoing sternotomy, which was 16.7 days ($p = 0.03$).

Table 6. Comparative data

Variable	Isolated AVR via sternotomy	Isolated AVR via RAT	*p*-value[a]
Operation time (min)	297 ± 53.9	298.6 ± 45.3	0.876
CPB (min)	148.6 ± 15.1	155.1 ± 32.8	0.876
ACC (min)	115.4 ± 14.9	113.9 ± 21.0	0.876
Ventilator time (hr)	17.4 ± 2.4	16.1 ± 4.2	0.639
Length of ICU stay (hr)	32.6 ± 10.4	33.6 ± 11.4	>0.999
Length of hospital stay (day)	16.4 ± 8.5	9.7 ± 3.8	0.030

Values are presented as mean ± standard deviation.
AVR, aortic valve replacement; RAT, right anterior thoracotomy; CPB, cardiopulmonary bypass time; ACC, aortic cross-clamp time; ICU, intensive care unit.
[a]The Mann-Whitney U test.

Discussion

Minimally invasive aortic valve procedures were introduced to cardiac surgery in the early 1990s. Since then, MiAVR has been increasingly attempted at many centers as an alternative to conventional AVR via full sternotomy, particularly when isolated AVR is indicated [11]. MiAVR via RAT is a safe and reproducible procedure associated with a low incidence of postoperative mortality and morbidity and a decreased length of hospital stay [12,13]. Some studies have shown that RAT AVR does not exhibit a significant difference in mortality or morbidity compared with that of standard median sternotomy; however, RAT AVR has been associated with a lower incidence of postoperative AF and blood transfusions, a shorter ventilation time and postoperative length of stay, and reduced postoperative pain [12-15]. The RAT AVR group exhibited a lower incidence of postoperative AF than the sternotomy group. This could be attributed to factors such as smaller incisions, sternal preservation, and intact costal cartilage, which collectively contribute to decreased postoperative pain, thereby triggering less postoperative AF [12]. Furthermore, it is presumed that the RAT AVR approach results in diminished postoperative bleeding and drainage, further contributing to a decreased incidence of AF. Additionally, MiAVR offers beneficial effects such as faster recovery, reduced pain, and improved cosmetic results [4]. TAVR has been increasingly used as the standard treatment option for patients with AS. However, it is not considered a treatment option for patients with AR. Therefore, surgical AVR has traditionally been the preferred treatment for AR [1,11]. Nonetheless, the number of cases involving AVR via minimally invasive approaches in patients with AR has been increasing because of the numerous advantages of this method. However, few studies have specifically addressed MiAVR in patients with severe AR. In this study, we present the results of MiAVR using the RAT method in patients with chronic severe AR treated at a single center. Consistent with previous reports, this study demonstrated acceptable or better outcomes in terms of mortality, morbidity, pain, length of hospitalization, and recovery time [4,12-15]. Additionally, postoperative echocardiographic results showed significant decreases in LVEDD and LVESD compared to the preoperative data, indicating favorable cardiac remodeling during the acute phase.

According to the meta-analysis by Murtuza et al. [4], the average surgery time for RAT AVR was 209 minutes, which is shorter than the 285 minutes observed in our hospital. Similarly, the CPB and ACC times were 102 minutes and 72 minutes, respectively, in the meta-analysis, shorter than our hospital's times of 140 minutes and 104 minutes, respectively. The length of stay in the ICU was shorter at our hospital than in the meta-analysis data (25 hours vs. 43.2 hours), whereas the total length of stay was reportedly the same (9 days). Additionally, the postoperative complication and mortality rates were more favorable at our hospital. Although the sample size should be further increased for more robust conclusions, our research findings demonstrate comparable or even superior surgical outcomes compared with existing data [4,16].

When performing MiAVR in patients with moderate-to-severe AR, there are some differences compared to patients with AS, especially in the method of delivering cardioplegia for myocardial protection. In patients with AR, antegrade cardioplegia through the root cannula may be ineffective in protecting the myocardium [17,18]. The available options include direct cardioplegia infusion via the coronary ostia, retrograde cardioplegia through the coronary sinus, and a combination of direct and retrograde methods. However, retrograde cardioplegia may inherently provide inadequate protection to the right ventricular and posterior LV myocardium. Administering retrograde cardioplegia also requires careful monitoring of the coronary sinus pressure and catheter position because problems such as catheter malposition and coronary sinus rupture can occur during retrograde cardioplegia infusion. The surgical field is limited in minimally invasive surgery (MIS). Thus, TEE is essential to confirm the proper location of the coronary sinus catheter. It is essential that a well-trained cardiologist or anesthesiologist confirms TEE during surgery; otherwise, it is difficult to properly position the catheter [19,20]. To overcome these limitations, cardioplegia was supplemented directly into the coronary ostia after aortotomy. Thus, it was imperative to ensure that direct cardioplegia infusion could be safely performed through a detailed preoperative workup, including coronary angiography and computed tomography. This was crucial because the efficacy of antegrade cardioplegia delivery often depends on collateral flow, which may be compromised by severe coronary artery stenosis. Therefore, careful consideration was given in identifying the location of the coronary ostium and arterial territory. All patients in our study

received direct antegrade cardioplegia infusion via the coronary ostia as they exhibited no specific abnormalities in the location of the coronary artery. In addition, no coronary stenosis was observed on the preoperative examination. In our experience, a commonly encountered problem during direct cardioplegia infusion in the surgical field is the difficulty in clearly visualizing the right coronary ostium compared with the left main ostium within the limited space. To overcome this challenge, we used several strategies. First, we identified the location of the right coronary ostium in advance, using the preoperative workup mentioned above. Second, we identified the location of the right coronary ostial protrusion while dissecting the outside aortic root prior to aortic cross-clamping. Finally, after aortotomy, the right coronary cusp or annulus was shifted backward and rightward to facilitate locating the ostium of the right coronary artery.

As mentioned above, utilizing the RD valve conferred the advantage of significantly reducing the surgical time by up to 60 minutes. However, no differences were identified in the postoperative complications or hospitalization days between the RD and non-RD valve groups. Therefore, when performing MiAVR in patients with AR, surgeons may consider shortening the surgery time using the RD valve unless there are contraindications, such as the presence of a bicuspid valve.

Our study has some limitations. First, it is based on a retrospective analysis of our institutional, observational, and prospectively collected database. Another potential source of bias might be the mindset of the postoperative care team, who could consciously treat patients with RAT differently (with fewer transfusions, early extubation, and discharge). In addition, the number of patients was relatively small and highly selective, making it difficult to draw definitive conclusions or identify statistically significant differences. Therefore, these results may not be generalizable. Further prospective studies should be conducted to validate the advantages of MiAVR.

Despite its numerous advantages, MiAVR also has several limitations. First, with MIS, many surgeons inevitably face a learning curve that can increase entry barriers for young surgeons [21]. Second, because the surgical field is limited compared to that of full or partial sternotomy, it may be challenging to address problems if they occur. Third, the use of femoral cannulation and perfusion may lead to groin complications (e.g., infections and arterial dissections/hematoma), contributing to morbidity not typically observed with conventional sternotomy. Retrograde aortic dissection may also occur [22]. However, a thorough understanding of MIS and experience with the technique can overcome these problems. Despite these drawbacks, MIS offers more advantages than disadvantages, and its benefits are evident. Therefore, it is important to continue developing and conducting experiments using MIS.

Despite its disadvantages and limitations, MIS is a competent modern and future surgical method. Our center's experience with MiAVR demonstrates the feasibility of adopting MIS techniques in patients with AR. Furthermore, MiAVR in patients with severe chronic AR offers the opportunity to reduce invasiveness of the surgical procedure, facilitate faster recovery, and achieve better surgical outcomes with fewer complications.

Article information

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Funding

None.

Author contributions

Conceptualization: all authors; Data curation: EYJ, SSL; Formal analysis: EYJ, HKM, JEI; Investigation, Validation: EYJ; Methodology, Project administration, Supervision: HKM; Resources: EYJ, JEI; Writing-original draft: EYJ; Writing-review & editing: all authors.

ORCID

Eun Yeung Jung, https://orcid.org/0000-0001-9890-8882
Ji Eun Im, https://orcid.org/0000-0003-1904-6810
Ho-Ki Min, https://orcid.org/0000-0003-4852-536X
Seok Soo Lee, https://orcid.org/0000-0002-4402-0885

References

1. Markham R, Ghodsian M, Sharma R. TAVR in patients with pure aortic regurgitation: ready to use? Curr Cardiol Rep 2020;22:98.
2. Wang Y, Shi J, Li F, Wang Y, Dong N. Aortic valve replacement for severe aortic regurgitation in asymptomatic patients with normal ejection fraction and severe left ventricular dilatation. Interact Cardiovasc Thorac Surg 2016;22:425–30.
3. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP, Gentile F, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association joint committee on clinical practice guidelines. Circulation 2021;143:e72–227.
4. Murtuza B, Pepper JR, Stanbridge RD, Jones C, Rao C, Darzi A,

et al. Minimal access aortic valve replacement: is it worth it? Ann Thorac Surg 2008;85:1121–31.
5. Bonow RO, Lakatos E, Maron BJ, Epstein SE. Serial long-term assessment of the natural history of asymptomatic patients with chronic aortic regurgitation and normal left ventricular systolic function. Circulation 1991;84:1625–35.
6. Jawarkar M, Manek P, Wadhawa V, Doshi C. Mini-bentall surgery: the right thoracotomy approach. J Chest Surg 2021;54:554–7.
7. Wong CH, Chan JS, Sanli D, Rahimli R, Harky A. Aortic valve repair or replacement in patients with aortic regurgitation: a systematic review and meta-analysis. J Card Surg 2019;34:377–84.
8. Duran CM. Aortic valve repair and reconstruction. Oper Tech Card Thorac Surg 1996;1:1515–29.
9. Boodhwani M, de Kerchove L, Glineur D, Poncelet A, Rubay J, Astarci P, et al. Repair-oriented classification of aortic insufficiency: impact on surgical techniques and clinical outcomes. J Thorac Cardiovasc Surg 2009;137:286–94.
10. Im JE, Jung EY, Lee SS, Min HK. Right anterior mini-thoracotomy aortic valve replacement versus transcatheter aortic valve implantation in octogenarians: a single-center retrospective study. J Yeungnam Med Sci 2024;41:96–102.
11. Zubarevich A, Rad AA, Amanov L, Szczechowicz M, Osswald A, Torabi S, et al. Sutureless aortic valve replacement in pure aortic regurgitation: expanding the indications. J Cardiothorac Surg 2022;17:198.
12. Glauber M, Miceli A, Gilmanov D, Ferrarini M, Bevilacqua S, Farneti PA, et al. Right anterior minithoracotomy versus conventional aortic valve replacement: a propensity score matched study. J Thorac Cardiovasc Surg 2013;145:1222–6.
13. Sharony R, Grossi EA, Saunders PC, Schwartz CF, Ribakove GH, Baumann FG, et al. Propensity score analysis of a six-year experience with minimally invasive isolated aortic valve replacement. J Heart Valve Dis 2004;13:887–93.
14. Aris A, Cámara ML, Montiel J, Delgado LJ, Galán J, Litvan H. Ministernotomy versus median sternotomy for aortic valve replacement: a prospective, randomized study. Ann Thorac Surg 1999;67:1583–7.
15. Dogan S, Dzemali O, Wimmer-Greinecker G, Derra P, Doss M, Khan MF, et al. Minimally invasive versus conventional aortic valve replacement: a prospective randomized trial. J Heart Valve Dis 2003;12:76–80.
16. Yousuf Salmasi M, Hamilton H, Rahman I, Chien L, Rival P, Benedetto U, et al. Mini-sternotomy vs right anterior thoracotomy for aortic valve replacement. J Card Surg 2020;35:1570–82.
17. Kawazoe K, Izumoto H, Satoh Y, Eishi K, Ishibashi K. Annuloaortic repair in the treatment of aortic regurgitation and aortic root pathology. Surg Today 2001;31:27–31.
18. Ito J, Nakanaga H, Fujii H, Tabata M. Endoscopically assisted selective antegrade cardioplegia in minimally invasive aortic valve replacement for patients with aortic insufficiency. JTCVS Tech 2023;18:28–36.
19. Allen BS, Winkelmann JW, Hanafy H, Hartz RS, Bolling KS, Ham J, et al. Retrograde cardioplegia does not adequately perfuse the right ventricle. J Thorac Cardiovasc Surg 1995;109:1116–26.
20. Langenberg CJ, Pietersen HG, Geskes G, Wagenmakers AJ, Soeters PB, Durieux M. Coronary sinus catheter placement: assessment of placement criteria and cardiac complications. Chest 2003;124:1259–65.
21. Di Eusanio M, Berretta P. The sutureless and rapid-deployment aortic valve replacement international registry: lessons learned from more than 4,500 patients. Ann Cardiothorac Surg 2020;9:289–97.
22. Schmitto JD, Mokashi SA, Cohn LH. Minimally-invasive valve surgery. J Am Coll Cardiol 2010;56:455–62.