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Right anterior mini-thoracotomy aortic valve replacement versus transcatheter aortic valve implantation in octogenarians: a single-center retrospective study

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Background: The aim of this study was to compare the early outcomes of octogenarians undergoing minimally invasive right anterior mini-thoracotomy aortic valve replacement (RAT-AVR) with those undergoing transcatheter aortic valve implantation (TAVI) for aortic valve disease.

Methods: In this single-center retrospective study, data were collected from octogenarians before and after RAT-AVR and TAVI between January 2021 and July 2022. Short-term outcomes, including the length of hospital stay, in-hospital mortality, all-cause mortality, and other major postoperative complications, were compared and analyzed.

Results: There were no significant differences in in-hospital mortality, stroke, acute kidney dysfunction requiring renal replacement therapy, length of intensive care unit stay, or length of hospital stay. However, the TAVI group had a higher incidence of permanent pacemaker insertion (10% vs. 0%, $p=0.54$) and paravalvular leaks (75% vs. 0%, $p<0.001$).

Conclusion: In the present study on octogenarians, both TAVI and RAT-AVR showed comparable short-term results. Although both procedures were considered safe and effective in the selected group, RAT-AVR had a lower incidence of complete atrioventricular block and paravalvular regurgitation.

Keywords: Aortic stenosis; Aortic valve replacement; Minimally invasive surgical procedures; Octogenarians; Transcatheter aortic valve implantation

Introduction

As the age of the general population advances, degenerative aortic valve disease, mainly aortic stenosis (AS), has become the most common heart valve disease in elderly people [1]. Surgical aortic valve replacement (SAVR) is the most effective treatment for patients with acceptable surgical risk profiles. SAVR has excellent perioperative mortality, morbidity, and long-term survival rates [2]. Nonetheless, a significant proportion of older patients with multiple comorbidities do not undergo surgical procedures because of the high surgical risk. Recent guidelines recommend transcatheter aortic valve implantation (TAVI) as an alternative to

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SAVR in high- and intermediate-risk patients [3,4]. Elderly patients are also eligible for TAVI regardless of their risk profile. However, owing to the possibility of major side effects, such as paravalvular leak (PVL), conduction disturbances requiring permanent pacemaker (PPM) insertion, and a high incidence of neurological events, the quality and safety of TAVI still require improvement [5]. In the field of surgery, efforts have been made to reduce the invasiveness of SAVR and surgical trauma. As experienced centers have developed safe and efficient surgical treatment options that increase patient satisfaction and reduce complication rates, right anterior mini-thoracotomy aortic valve replacement (RAT-AVR) may be a viable alternative for high-risk patients with aortic valve disease from the viewpoint of less surgical trauma [6]. Therefore, this study aimed to compare the early outcomes of octogenarians undergoing RAT-AVR with those undergoing TAVI.

Methods

Ethical statements: This study was approved by the Institutional Review Board (IRB) of Yeungnam University Hospital (IRB No: 2023-03-024-003). The requirement for informed consent was waived due to the retrospective nature of the study.

1. Patients

Between January 2021 and July 2022, 11 octogenarian patients underwent RAT-AVR at our center. One patient with infective endocarditis was excluded to better understand the impact of age on surgical outcomes. Thus, 10 patients who underwent RAT-AVR were included in this study. During the same period, 20 octogenarians underwent TAVI in our cardiology department. The patient data were compared between the RAT-AVR (n = 10) and TAVI (n = 20) groups.

We retrospectively reviewed medical records to obtain patient demographics, hemodynamic status, and preoperative and perioperative data. The preoperative variables included in the analysis were age, sex, body surface area, hypertension, diabetes mellitus, previous coronary intervention, chronic obstructive pulmonary disease, chronic kidney disease, arrhythmia, Society of Thoracic Surgeons (STS) score, and echocardiographic parameters (left ventricular ejection fraction [LVEF], aortic valve area, peak systolic pressure gradients [PSPGs], and mean systolic pressure gradients [MSPGs]). Surgical risk was defined as low risk (STS score < 4%), intermediate risk (STS score 4%–8%), or high risk (STS score > 8%). The baseline patient characteristics are summarized in Table 1.

When the octogenarians with severe AS were enrolled, surgical risk stratification was performed using a multidisciplinary heart team approach. Patients deemed high risk were treated with TAVI. SAVR was recommended for patients at low or intermediate risk, but TAVI was performed if the patient declined SAVR.

2. Surgical technique

After anesthesia induction and insertion of a double-lumen endotracheal tube, external defibrillator pads were placed on the patient in the supine position. Intraoperative transesophageal echocardiography (TEE) was performed on all patients. An approximately 6- to 7-cm skin incision from the sternochondral junction was made horizontally along the right second intercostal space anteriorly. After deflating the right lung, the right pleural cavity was entered, and the right internal thoracic artery and vein were divided using metal clips. The third costal cartilage was proximally disarticulated to obtain a better visual field. A soft tissue retractor (Alexis, Modesto, CA, USA) and a rib spreader were used for optimal exposure. After a pericardial incision was made 2 cm above the right phrenic nerve, multiple pericardial tagging sutures were placed on the skin. In most cases, after a small incision, the femoral artery and vein were used for peripheral cannulation to gain access to the inferior vena cava. Direct superior vena cava cannulation was performed for bicaval venous cannulation. If peripheral vascular dis-

Table 1. Baseline characteristics of patients

Variable	RAT-AVR group	TAVI group	*p*-value
No. of patients	10	20	
Age (yr)	84.0 (81.8–87.0)	83.0 (81.3–85.8)	0.54
Female sex	5 (50.0)	10 (50.0)	> 0.99
Body surface area (m^2)	1.59 (1.37–1.72)	1.55 (1.35–1.67)	0.57
Hypertension	5 (50.0)	14 (70.0)	0.43
Diabetes mellitus	0 (0)	6 (30.0)	0.07
COPD	2 (20.0)	0 (0)	0.10
Chronic kidney disease	0 (0)	5 (25.0)	> 0.99
Coronary artery disease	4 (40.0)	4 (20.0)	> 0.99
Cardiac rhythm			
Sinus rhythm	9 (90.0)	17 (85 .0)	0.53
Atrial fibrillation	1 (10.0)	3 (15.0)	0.53
STS score[a]	3.33 (2.44–5.97)	3.94 (2.28–5.90)	0.79
Low	6 (60.0)	11 (55.0)	
Intermediate	4 (40.0)	6 (30.0)	
High	0 (0)	3 (15.0)	

Values are presented as number only, median (interquartile range), or number (%).
RAT-AVR, right anterior mini-thoracotomy aortic valve replacement; TAVI, transcatheter aortic valve implantation; COPD, chronic obstruction pulmonary disease; STS, Society of Thoracic Surgeons.
[a]Low risk, STS score < 4%; intermediate risk, STS score 4%–8%; or high risk, STS score > 8%.

ease was suspected on preoperative work-up or severe atherosclerotic disease was evident on TEE, right axillary artery cannulation was performed for antegrade arterial perfusion to reduce embolic events. Cardiopulmonary bypass (CPB) was performed after systemic heparinization, and the left ventricle was vented via the right superior pulmonary vein. Continuous flushing of the pleural cavity with carbon dioxide was used to decrease the risk of air embolism. Depending on the grade of aortic regurgitation, myocardial protection was achieved with antegrade cardioplegia delivered through the root cannula (regurgitation grade less than mild) or directly to the coronary ostia after aortotomy (regurgitation grade higher than mild). The ascending aorta was clamped with a flexible aortic cross clamp (ACC; Cygnet clamp, Norvare Surgical System, Inc., Cupertino, CA, USA) through the operative window. After placing the ACC, transverse aortotomy was performed approximately 1 cm above the sinotubular junction. After three retracting sutures were placed at the commissures and tagged to the skin, the diseased aortic valve and calcified tissue were removed. For sutured SAVR, the prosthetic valve was affixed in the supra-annular position of the aortic annulus using interrupted pledgeted sutures. For a rapid-deployment valve (RDV; Intuity, Edward Lifesciences, Irvine, CA, USA), three non-pledgeted guiding sutures were placed as simple sutures at the nadir of each aortic cuspid. The suture was passed through the sewing ring of the valve and snared using a tourniquet. The valve was positioned in the annulus and the snares were secured. A balloon catheter was inserted through the device and locked into the aortic annulus. Normal saline was injected until the target pressure was reached. The pressure required for balloon expansion was maintained for 10 seconds. After the valve was deployed, the holding device and valve holder were removed concurrently. Three guiding sutures were then tied [7]. After confirming establishment of a well-seated prosthetic valve, the aortotomy was closed by using continuous over-and-over sutures. After placement of a temporary pacing wire, the ACC was removed, and the patient was weaned from CPB. The third costal cartilage was fixed using two interrupted sutures (vicryl 1-0) during wound closure. Associated procedures were performed, including one root enlargement procedure and one ascending aortic replacement.

3. Transcatheter aortic valve implantation procedure

The right common femoral artery (CFA) was punctured under general anesthesia using standard percutaneous access techniques for valve insertion. Under pacing with a temporary pacemaker, a balloon was inserted, guided to the aortic valve, and inflated. The valve was then inserted through the right CFA sheath and deployed over the aortic annulus under fluoroscopic and intraoperative TEE guidance to prevent size discrepancies. Transthoracic echocardiography was performed 1 day after the procedure to check for valve motion and perivalvular aortic regurgitation.

4. Statistical analysis

As the sample size of this study was small and the variables did not satisfy a normal distribution, statistical comparisons were made using non-normal distribution assumptions. Baseline characteristics are presented as median values and interquartile ranges (IQRs) unless otherwise indicated. All values are expressed as two-tailed probabilities. The proportions of the two groups were compared using the Fisher exact test. Differences between the two groups were analyzed using the Mann-Whitney U-test. Statistical significance was set at $p < 0.05$.

Results

The median patient age was 84 years (IQR, 81.8–87 years) in the RAT-AVR group and 83 years (IQR, 81.3–85.8 years) in the TAVI group. The median STS scores were 3.33 (IQR, 2.44–5.97) in the RAT-AVR group and 3.94 (IQR, 2.28–5.9) in the TAVI group. The proportions of patients with hypertension and diabetes were higher in the TAVI group (hypertension, 70% vs. 50%; diabetes, 30% vs. 0%). The basic characteristics of the study patients are summarized in Table 1. In the RAT-AVR group, eight patients had pure AS, and two patients had mixed aortic valve disease. All the patients in the TAVI group had AS. The median of LVEF was 56.0% (IQR, 41.5%–63.3%) in the RAT-AVR group and 62.5% (IQR, 58.0%–70.0%) in the TAVI group. The preoperative data are summarized in Table 2. In this study, two patients with bicus-

Table 2. Preoperative hemodynamic data

Variable	RAT-AVR group (n = 10)	TAVI group (n = 20)	*p*-value
Aortic valve lesion			
Stenosis	8 (80.0)	20 (100)	
Regurgitation	0 (0)	0 (0)	
Mixed	2 (20.0)	0 (0)	
Valve etiology			
Degenerative	10 (100)	20 (100)	0.10
Bicuspid	2 (20.0)	0 (0)	0.33
LVEF (%)	56 (41.50–63.30)	62.50 (58.00–70.00)	0.04
Aortic valve area (m^2)	0.86 (0.82–0.93)	0.78 (0.63–0.92)	0.39
PSPG (mmHg)	63.40 (58.85–97.83)	76.65 (70.43–98.63)	0.22
MSPG (mmHg)	37.80 (33.50–67.30)	45.20 (43.00–62.05)	0.07

Values are presented as number (%) or median (interquartile range).
RAT-AVR, right anterior mini-thoracotomy aortic valve replacement; TAVI, transcatheter aortic valve implantation; LVEF, left ventricular ejection fraction; PSPG, peak systolic pressure gradient; MSPG, mean systolic pressure gradient.

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pid aortic valves (BAVs) were included in the RAT-AVR group. In general, BAV is a contraindication for implantation of an RDV because the asymmetry of the BAV aortic root may increase the risk of PVL or possible dislocation of the RDV [8]; surgery was performed on these patients using a sutured valve. The procedural data are presented in Table 3. In the RAT-AVR group, concomitant procedures were performed on two patients, including one patient who underwent root enlargement due to a small aortic root and one patient who underwent ascending aortic replacement. In the RAT-AVR group, the CPB time and ACC time were 160.6 ± 58.5 minutes and 120.5 ± 56.3 minutes, respectively. After excluding two patients with associated procedures, the CPB time and ACC time were 137.5 ± 29.1 minutes and 102.9 ± 25.6 minutes, respectively, in the eight remaining patients who received RAT-AVR. No patient required full median sternotomy in the RAT-AVR group.

After surgery, the MSPG was 9.67 mmHg (IQR, 6.97–11.38 mmHg) and 11.25 mmHg (IQR, 9.36–14.3 mmHg) ($p = 0.20$) and the PSPG was 16.8 mmHg (IQR, 13.4–19.8 mmHg) and 22.6 mmHg (IQR, 17.7–27.1 mmHg) ($p = 0.03$) in the RAT-AVR and TAVI groups, respectively (Table 4). The incidence of less than mild PVL was significantly higher in the TAVI group (75% vs. 0%, $p < 0.001$). No cases of moderate or severe PVL were reported in either group. A PPM was implanted in two patients (10.0%) in the TAVI group because of complete atrioventricular block (CAVB). None of the patients developed CAVB in the RAT-AVR group, and none had rhythm disturbances, such as left bundle branch block.

The early outcomes of all patients are summarized in Table 5. Two patients in the RAT-AVR group underwent revision due to bleeding, one from the right internal thoracic artery due to de-clipping, and the other from the site of the root cannula insertion. Two patients in the TAVI group experienced post-procedural bleeding.

The incidences of newly required dialysis and early stroke were

Table 3. Procedural data

Variable	Data
RAT-AVR	10
Concomitant cardiac surgery	
Root enlargement	1
Ascending aorta replacement	1
Type of prosthesis	
Bioprosthetic	10
Sutureless	8
Sutured	2
Mechanical	0
Valve size (mm)	
19	2
21	2
23	6
25	0
CPB time (min)	160.6 ± 58.5
ACC time (min)	120.5 ± 56.3
TAVI	20
Type of valve	
CoreValve[a]	8
Sapien 3	12
Valve size (mm)	
20	1
23	7
26	8
29	4

Values are presented as number only or mean ± standard deviation.
RAT-AVR, right anterior mini-thoracotomy aortic valve replacement; TAVI, transcatheter aortic valve implantation; CPB, cardiopulmonary bypass time; ACC, aortic cross clamp.
[a]CoreValve, Medtronic Inc., MN, USA; Sapien 3, Edwards Lifesciences Inc., Irvine, CA, USA.

Table 4. Hemodynamic results

Variable	RAT-AVR group (n = 10)	TAVI group (n = 20)	*p*-value
Permanent pacemaker	0 (0)	2 (10.0)	0.54
Low	0 (0)	1 (50.0)	
Intermediate	0 (0)	1 (50.0)	
High	0 (0)	0 (0)	
Paravalvular leak	0 (0)	15 (75.0)	< 0.001
Low	0 (0)	7 (46.7)	
Intermediate	0 (0)	6 (40.0)	
High	0 (0)	2 (13.3)	
PSPG (mmHg)	16.8 (13.4–19.8)	22.6 (17.7–27.1)	0.01
MSPG (mmHg)	9.67 (6.97–11.38)	11.25 (9.36–14.3)	0.08

Values are presented as number (%) or median (interquartile range).
RAT-AVR, right anterior mini-thoracotomy aortic valve replacement; TAVI, transcatheter aortic valve implantation; PSPG, peak systolic pressure gradient; MSPG, mean systolic pressure gradient.

Table 5. Early clinical outcomes

Variable	RAT-AVR group (n = 10)	TAVI group (n = 20)	*p*-value
Reoperation[a]	2 (20.0)	2 (10.0)	0.58
Newly required dialysis	0 (0)	0 (0)	> 0.99
Early stroke	0 (0)	0 (0)	> 0.99
In-hospital mortality (%)	0 (0)	1 (5)	> 0.99
Length of stay in ICU (day)	2 (1–2)	1.5 (1–2)	0.65
Length of hospital stay (day)	9.5 (4–17)	5 (5–10)	0.29

Values are presented as number (%) or median (interquartile range).
RAT-AVR, right anterior mini-thoracotomy aortic valve replacement; TAVI, transcatheter aortic valve implantation; ICU, intensive care unit.
[a]The reason for the reoperation was bleeding.

not significantly different between the two groups. The in-hospital mortality rate was 5.0% (n = 1) in the TAVI group and 0% in the RAT-AVR group ($p = 0.25$). One patient in the TAVI group died after neurosurgery due to intracerebral and intraventricular hemorrhage. The length of hospital stay was shorter in the TAVI group than in the RAT-AVR group (5 days vs. 9.5 days, $p = 0.29$), but the difference was statistically significant.

Discussion

To the best of our knowledge, previous data evaluating and comparing postoperative outcomes between octogenarian patients undergoing RAT-AVR and those undergoing TAVI are rare. The early results of RAT-AVR in patients of this age were favorable in terms of mortality rate, PVL incidence, and requirement for PPM insertion. Previous studies have shown that the early mortality rate after SAVR in octogenarians ranged from 3% to 13% [9]. Despite the limited population size in our study, there was no in-hospital mortality among the patients. These results are similar to those of previous studies that demonstrated tolerable early mortality rates, even in elderly patients. This study indicates that patient age may not be a major exclusion criterion for RAT-AVR. Most patients in our study had a low or intermediate risk. Thus, RAT-AVR can be performed in well-selected patients older than 80 years with acceptable operative outcomes. Recent developments in surgical methods may further improve RAT-AVR results in octogenarians.

TAVI has recently been regarded as a valid alternative treatment for inoperable high-risk patients [4]. However, compared with conventional surgery, its effects on postoperative mortality, morbidity, and long-term outcomes are debatable. Investigators in cohort A of the PARTNER (Placement of AoRtic TraNscathetER Valves) trial showed similar 30-day mortality and 2-year survival rates in high-risk patients in both treatment groups [10]. However, a recent study showed that TAVI was likely to be less effective in lowering early and intermediate all-cause mortality than SAVR [11].

TAVI is associated with an increased risk of neurological events and PVLs, which are known risk factors for decreased survival [2]. A major limitation of these studies was the use of conventional surgery, comprising a full sternotomy and a sutured aortic valve. Several studies have indicated higher rates of PVL associated with TAVI. The presence of PVL is a risk factor for lower survival rates [12]. In our study, 15 patients (75.0%) in the TAVI group had at least mild PVL, whereas none in the RAT-AVR group had mild PVL. This surgical approach has an advantage over TAVI in that it removes the calcified stenotic valve, thereby lowering the risk of PVL and neurological events [3]. We agree that the complete decalcification of the aortic rings can decrease the risk of leakage. This mechanism is still under investigation but may be related to remnant calcified aortic leaflets forming an irregular annulus into which the transcatheter valve is inserted [13]. The incidence of postoperative PVL did not increase because of using a sutureless valve through a surgical approach, with rates remaining below 1% [14]. Surgical resection of the valve leaflets and decalcification of the aortic annulus before valve replacement may be important factors in reducing the incidence of PVL.

The PPM requirements were significantly higher after TAVI than after RAT-AVR. In previous studies, the PPM insertion rate after TAVI ranged from 8% to 40% [15,16]. In most trials, the published PPM rates after SAVR ranged from 2.0% to 11.8%, including studies with matched high-risk patients [17,18]. These rates were significantly lower than those for TAVI. Extensive registry data have shown that patients requiring PPM implantation after SAVR have reduced long-term survival from all causes. This reduction in survival time was also apparent in patients who received TAVI with short-term follow-ups [19]. Our study also showed that the PPM insertion rate was higher after TAVI than after RAT-AVR.

Two surgical options have recently been considered as alternatives to TAVI for treating high-risk patients: (1) minimally invasive surgical approaches and (2) sutureless or rapid-deployment aortic valve prosthesis [20]. Although minimally invasive AVR is advantageous for reducing surgical trauma and related complications, its application may be limited by longer CPB and ACC times, suggesting that exposure is longer and stented prosthetic valve implantation is more difficult than with conventional approaches. However, this can be overcome by inserting a sutureless or RDV prosthesis and using an automated fastener (Cor-Knot, LSI SOLUTIONS, Victor, NY, USA). Thus, RAT-AVR has excellent hemodynamic performance. Postoperative complications and PVL make this method a practical alternative to the new TAVI technique for operable, high-risk patients [3]. No significant differences in in-hospital mortality or serious postoperative complications were observed between groups in our study.

Few studies have focused on clinical outcomes comparing RAT-AVR and TAVI according to surgical risk stratification. Our results support the efficacy and safety of RAT-AVR which is associated with better outcomes than those of TAVI in low- and intermediate-risk octogenarians. The results of this study also suggest that the early mortality rates of patients undergoing RAT-AVR and TAVI are similar in well-selected patients.

This study had several limitations. First, the number of patients was small and highly selective, making it difficult to draw definitive conclusions and generate statistically significant differences. Sec-

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ond, this was a single-center, retrospective, observational study. Third, it was difficult to accurately comment on the complication rate as our study evaluated early outcomes. Fourth, when comparing the two groups of patients, no high-risk patients were included in the RAT-AVR group, which is likely to have the potential for selection bias and compromise the assessment of surgical benefits if they differed between the groups. Therefore, these results may not be generalizable.

With the use of TAVI as a surgical alternative for high-risk patients requiring AVR, the outcomes of these patients have emerged as a focus of interest. Although the results of our study indicate that age is not a significant risk factor for selecting SAVR in elderly patients, appropriate patient selection for RAT-AVR and TAVI remains an important challenge, particularly in elderly patients. Despite the limitations of this study, RAT-AVR and TAVI provided similar short-term mortality rates in appropriately selected octogenarians with severe AS and low or intermediate surgical risk, and RAT-AVR had a lower incidence of postoperative PPM insertion and PVL. However, long-term high-quality studies are needed to further evaluate these findings.

Article information

Conflicts of interest

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

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Author contributions

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

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