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Original Article

Midterm Outcomes of Right Anterior Mini Thoracotomy Aortic Valve Replacement

Ali Fatehi Hassanabad, MD, MSc,[a] Mortaza Fatehi Hassanabad, MSc,[a] Muhammad Israr-Ul-Haq, BN,[a] Andrew Maitland, MD,[a] and William D.T. Kent, MD, MSc[a]

[a] *Section of Cardiac Surgery, Department of Cardiac Sciences, Libin Cardiovascular Institute, University of Calgary, Calgary, Alberta, Canada*

ABSTRACT

Background: Contemporary surgical approaches for aortic valve replacement (AVR) include full median sternotomy, hemi-sternotomy, and a right anterior mini thoracotomy (RAMT) approach. We report the midterm outcomes of RAMT for isolated AVR.

Methods: A retrospective study was conducted, reporting the midterm outcomes of patients who underwent isolated RAMT AVR. The primary outcomes were death and disabling stroke within 30-days of surgery. The secondary outcomes were survival at latest follow-up assessment, hospital readmission for aortic valve disease, prosthetic valve function, and incidence of structural valve deterioration requiring reintervention on the aortic valve.

Results: Seventy patients underwent isolated RAMT AVR between February 2016 and February 2018. One patient died from a cardiac cause within 30 days of surgery, whereas none experienced disabling

RÉSUMÉ

Contexte : Les approches chirurgicales contemporaines pour le remplacement de la valve aortique (RVA) incluent la sternotomie médiane complète, l'hémisternotomie et la mini thoracotomie antérieure droite (MTAD). Nous rapportons les résultats à moyen terme de la MTAD pour le RVA isolé.

Méthodes : Une étude rétrospective a été menée, rapportant les résultats à moyen terme des patients ayant subi un RVA isolé avec MTAD. Les principaux résultats étaient le décès et l'accident vasculaire cérébral (AVC) invalidant, dans les 30 jours suivant l'intervention chirurgicale. Les résultats secondaires étaient la survie lors de la dernière évaluation de suivi, la réadmission à l'hôpital pour une maladie de la valve aortique, la fonction de la valve prothétique et l'incidence de la détérioration structurelle de la valve nécessitant une réintervention sur la valve aortique.

Full sternotomy (FS) is the conventional approach for surgical aortic valve replacement (SAVR).[1-3] However, up to 40% of patients referred for AVR are denied surgery, due to their age, frailty, and high-risk profile.[4] As transcatheter aortic valve replacement (TAVR) continues to evolve, many of these patients will be treated. However, not all patients are candidates for TAVR,[5] and some may benefit from minimally invasive AVR (MIAVR), as an alternative. MIAVR also may be a good option for healthy patients with low surgical risk, offering advantages over both FS AVR and TAVR.[6]

Compared to FS, MIAVR has been associated with less bleeding, fewer arrhythmias, better cosmesis, shorter hospital stay, and less postoperative pain.[7-24] Although the most-common MIAVR approach is an upper hemisternotomy, a right anterior mini-thoracotomy (RAMT) is sternum-sparing, and it has the advantages of less blood loss, better postoperative mobility, and shorter hospital length-of-stay.[10,13,15,25] Studies also have found that RAMT is more cost-effective, compared to sternum-based strategies.[26,27] Despite these advantages, RAMT is not used widely, and the midterm outcomes are not well understood. Herein, we present the 5-year outcomes of isolated, first-time, RAMT AVR.

Methods

Study design and patient cohort

This is a midterm follow-up assessment of a retrospective study on patients who underwent first-time, isolated RAMT AVR at a large, tertiary-care Canadian centre. Chart review identified 72 patients who were operated on by 2 surgeons between February 2016 (the beginning of our RAMT AVR program) and February 2018. Two patients were relocated to a different jurisdiction at the time of the follow-up assessment, so they were missing data and were therefore excluded from the study. The study was approved by the institutional research ethics board. An enhanced protocol for recovery after

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Corresponding author: Ali Fatehi Hassanabad, MD, MSc, Section of Cardiac Surgery, Department of Cardiac Sciences, Libin Cardiovascular Institute, Cumming School of Medicine, University of Calgary, Foothills Medical Centre, 880, 1403 29th Street NW, Calgary, Alberta T2N 2T9, Canada. Tel.: +1-403-944-5480; fax: +1-403-355-4035.

E-mail: ali.fatehihassanabad@ahs.ca

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postoperative strokes. The mean follow-up period for the cohort was 74.46 ± 7.54 months. At 95 months, a total of 49 patients were alive. During the follow-up period, 2 patients underwent median sternotomy, 1 for mitral valve replacement and tricuspid repair, and 1 for coronary artery bypass grafting. At last follow-up assessment, the average mean transvalvular gradient was 12.11 ± 9.15 mm Hg. One patient developed prosthetic valve infective endocarditis, and 1 patient was found to have prosthetic valve thrombosis. Prosthetic valve function was normal in 66 patients. At 95 months, freedom from aortic valve reintervention was 98.6%, as 1 patient required redo aortic root surgery.

Conclusions: RAMT AVR can be done safely in the appropriate patient population. Midterm outcomes at our centre are promising, and they suggest that this approach is a good option for managing aortic stenosis.

Résultats : Soixante-dix patients ont subi un RVA isolé avec MTAD entre février 2016 et février 2018. Un patient est décédé d'une cause cardiaque dans les 30 jours suivant l'intervention, tandis qu'aucun n'a subi d'AVC postopératoire invalidant. La période de suivi moyenne de la cohorte était de 74,46 ± 7,54 mois. À 95 mois, un total de 49 patients étaient encore en vie. Au cours de la période de suivi, 2 patients ont subi une sternotomie médiane, 1 pour un remplacement de la valve mitrale et une réparation de la tricuspide, et 1 pour un pontage aorto-coronarien. Lors de la dernière évaluation de suivi, le gradient transvalvulaire moyen était de 12,11 ± 9,15 mmHg. Un patient a développé une endocardite infectieuse de la valve prothétique et 1 patient a présenté une thrombose de la valve prothétique. La fonction de la valve prothétique était normale chez 66 patients. À 95 mois, l'absence de réintervention sur la valve aortique était de 98,6 %, 1 patient ayant dû subir une nouvelle chirurgie de la racine aortique.

Conclusions : Le RVA avec MTAD peut être réalisé en toute sécurité dans une population de patients appropriée. Les résultats à moyen terme, dans notre centre, sont prometteurs et suggèrent que cette approche est une bonne option pour la gestion de la sténose aortique.

the cardiac surgery was not applied to this patient cohort. Moreover, to provide context, 130 and 20 patients underwent FS AVR and upper sternotomy AVR at our centre, respectively, during the same time period, although they were not investigated in the present study.

Patient selection for RAMT AVR

Our approach for selecting potential RAMT AVR candidates has been reported previously.[28] Briefly, all patients receive a computed tomography scan of their chest and peripheral vessels. The ideal candidate has the following characteristics: they do not have an elevated body mass index; their aorta is not be shifted leftward; the distance from their aortic valve to the incision is < 9 cm; and their peripheral vessels are suitable for instituting cardiopulmonary bypass (CPB). A RAMT can be considered for young patients who are motivated to return to work quickly (ie, those who would prefer to avoid following sternal precautions), and for the frail patients who may struggle with a conventional FS AVR. Although a RAMT approach is possible,[29] particularly for those surgeons who are novices in minimally invasive procedures, we suggest that a RAMT approach not be adopted in patients who have undergone cardiac surgery in the past. Finally, a RAMT may not be ideal in either patients who previously have received chest radiation therapy, owing to the potential for development of intrathoracic adhesions, or those with active aortic valve endocarditis.

Study endpoints

Primary outcomes were death and disabling stroke within 30 days of surgery for this cohort of patients. Secondary outcomes were survival at latest follow-up assessment, hospital readmission for aortic valve disease, prosthetic valve function (transvalvular mean pressure gradient and paravalvular leak [PVL]), and incidence of structural valve deterioration requiring reintervention on the aortic valve.

Follow-up considerations

Charts were reviewed to ensure that all patients had a transthoracic echocardiogram at the latest follow-up assessment, which was performed a minimum of 5 years after their index RAMT AVR. Charts also were reviewed to determine whether patients required rehospitalization for any cardiovascular-related issues, including heart failure, presyncope and/or syncope, and infective endocarditis. Patients with missing data were excluded from this study.

Results

Baseline patient demographics

After excluding 2 patients because they had missing follow-up data, a total of 70 patients were included in the study. All patients were undergoing first-time, isolated RAMT AVR. Of these patients, 37 were male, and the mean age at the time of operation was 73.57 ± 10.03 years. A total of 55 patients underwent surgery on an elective basis, 3 on a semi-urgent basis, and 12 on an urgent basis. In all, 36 had hypertension, 34 had dyslipidemia, and 14 had diabetes. Although all patients had dyspnea, 16 presented with angina prior to their operation. A total of 25 patients had a bicuspid native aortic valve, 16 had preexisting atrial fibrillation, and none had active infective endocarditis at the time of their RAMT AVR. The mean calculated European System for Cardiac Operative Risk Evaluation (EuroSCORE) II for the cohort was 1.88% ± 1.31%. Baseline patient demographics are summarized in Table 1.

Intraoperative details

All cases were performed via the peripheral institution of CPB. Cannulation was completed after a cut-down was done to access the femoral vessels. The third rib was detached in 66 patients. Del Nido cardioplegia was administered for 61 patients. A Perceval sutureless prosthetic valve (Corcym LivaNova, London, United Kingdom) was deployed in 67 patients; a Carbomedics Top Hat supraannular aortic valve (Corcym LivaNova) was deployed in 2 patients, and an Edwards Intuity prosthetic valve (Edwards Lifesciences, Irvine, CA) was deployed in 1 patient. Of the Perceval valves

Table 1. Baseline patient demographics (n = 70)

Variable	Value
Age, y	73.57 ± 10.03
Gender, male	37 (53)
Hypertension	36 (510
Dyslipidemia	34 (49)
Type II diabetes	14 (20)
Renal insufficiency (eGFR < 60 mL/min per 1.73 m^2)	12 (17)
Peripheral arterial disease	7 (10)
Chronic obstructive lung disease	5 (7)
Cerebrovascular disease	1 (1)
Prior cerebrovascular event	3 (4)
Angina	16 (23)
CCS class	
I	4 (6)
II	11 (16)
III	1 (1)
Presyncope	12 (17)
Syncope	7 (10)
Dyspnea	70
NYHA class	
I	24 (34)
II	33 (47)
III	11 (16)
IV	2 (3)
Atrial fibrillation	16 (23)
Active infective endocarditis	0
Syncope (≥ 1 episode)	3 (4)
Bicuspid aortic valve	25 (36)
Rheumatic aortic valve disease	2 (3)
EuroSCORE II, %	1.88 ± 1.31

Values are mean ± standard deviation;, n (%), or n.

CCS, Canadian Cardiovascular Society; eGFR, estimated glomerular filtration rate; EuroSCORE, European System for Cardiac Operative Risk Evaluation; NYHA, New York Heart Association.

Table 2. Intraoperative details (n = 70)

Variable	Value
First-time	70
Isolated AVR	70
Peripheral cannulation	70
Cut-down on femoral vessels	70
Cardioplegia	
Custodial	9 (13)
Del Nido	61 (87)
Valve type	
Carbomedics Top Hat	2 (3)
Perceval	67 (96)
Intuity	1 (1)
Valve size	
Carbomedics Top Hat, mm	
23	1 (1)
25	1 (1)
Perceval	
Small	7 (10)
Medium	19 (28)
Large	20 (29)
Extra large	21 (30)
Intuity, mm	
21	1 (1)
Rib detached	66 (94)
Cardiopulmonary bypass time, min	84.23 ± 20.56
Aortic cross-clamp time, min	53.77 ± 15.21
Conversion to sternotomy	0
Transvalvular pressure gradient, mm Hg	7.87 ± 3.36
PVL	
None or trivial	68 (97)
Mild	2 (3)

Values are mean ± standard deviation, n (%), or n. The Carbomedics Top Hat supraannular aortic valve is from Corcym LivaNova (London, United Kingdom); the Perceval sutureless prosthetic valve is from Corcym LivaNova; the Edwards Intuity prosthetic valve is from Edwards Lifesciences (Irvine, CA).

AVR, aortic valve replacement; PVL, paravalvular leak.

received, 7 were small, 19 were medium, 20 were large, and 21 were extra large. No conversion to sternotomy took place in the cohort. The mean CPB and cross-clamp times were 84.23 ± 20.56 and 53.77 ± 15.21 minutes, respectively. A total of 68 patients had either no PVL or trivial PVL, and 2 had mild PVL. The average mean transvalvular pressure gradient was 7.87 ± 3.36 mm Hg. The intraoperative details are provided in Table 2.

Short-term postoperative outcomes

One patient died intraoperatively, but no further deaths occurred at 30 days after surgery. One patient had a left-hemisphere anterior cerebral artery and a middle cerebral artery watershed stroke after the operation but had no significant neurologic deficits upon his discharge on postoperative day 12. No patient required emergent reoperation due to excessive bleeding. A total of 3 patients required blood transfusions while they were in the cardiovascular intensive-care unit. A total of 14 patients developed new-onset postoperative atrial fibrillation. Two patients required implantation of a permanent pacemaker prior to their discharge. The mean and median lengths of hospital stay were 6.63 ± 5.65 days, and 5 days (interquartile range, 3), respectively. The short-term outcomes are summarized in Table 3.

Midterm postoperative outcomes

Patient-related outcomes. The mean duration of the follow-up period for the cohort was 74.46 ± 7.54 months. All patients were followed on a yearly basis. The longest and shortest follow-up periods were 95 and 60 months, respectively. At 95 months, a total of 49 patients were alive. Excluding the 1 intraoperative death that occurred, which resulted from iatrogenic aortic dissection, 2 patients died from congestive heart failure (one at 9 months, and the other at 72 months), 1 died from severe aortic stenosis (at 60 months), and 1 died from infective endocarditis (at 36 months). The

Table 3. Short-term outcomes (n = 70)

Variable	Value
30-d mortality	1 (1)
Postoperative stroke	1 (1)
Patients with neurologic deficits at discharge	0
Emergent reoperation	0
Transfusion of blood products in CVICU (patients)	3 (4)
Transfusion of blood products on the ward (patients)	3 (4)
New-onset POAF	14 (20)
Permanent pacemaker	2 (3)
Length of CVICU stay, d	
Mean	1.50 ± 1.23
Median (IQR)	1 (0)
Length of hospital stay, d	
Mean	6.63 ± 5.65
Median (IQR)	5 (3)

Values are n, or n (%), unless otherwise indicated.

CVICU, cardiovascular intensive-care unit; IQR, interquartile range; POAF, postoperative atrial fibrillation.

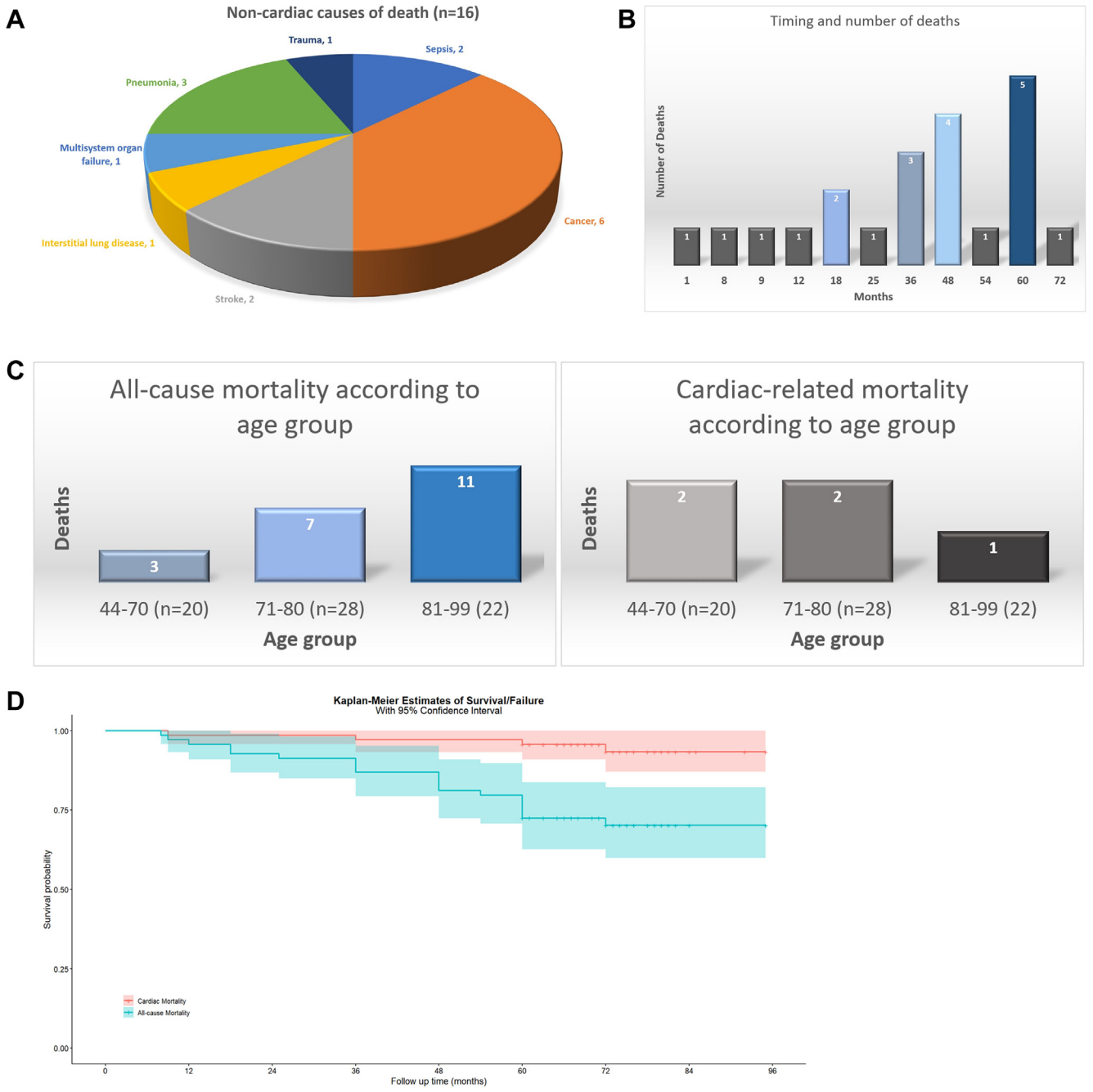

Figure 1. (**A**) Spectrum of the non-cardiac causes of death; (**B**) a histogram of the time-of-death for the patients in this series; (**C**) all-cause (**left**) and cardiac-related (**right**) deaths were also stratified according to age. (**D**) Survival rates from cardiac-related death (in **red**) and all-cause mortality (in **blue**).

other deaths were from noncardiac causes, including stroke, pneumonia, and malignancy. Figure 1A depicts the noncardiac causes of death, and Figure 1B is a histogram of the time-of-death for the patients in this series. Four patients in the cohort required rehospitalization for cardiac-related reasons, as follows: 1 for infective endocarditis (at 36 months); 1 for congestive heart failure (at 4 months); and 2 for symptoms secondary to severe aortic stenosis (both at 60 months). All-cause and cardiac-related deaths also were stratified according to age (Fig. 1C, left and right). Survival rates at the midterm follow-up assessment also were evaluated (Fig. 1D).

At the latest follow-up assessment, of the 14 patients who developed postoperative atrial fibrillation, only 3 remained in atrial fibrillation. At 60 months, the proportion of patients free from aortic valve reintervention was 98.6%, as 1 patient required aortic valve reintervention, indicated because of dissection in the aortic root, secondary to aortic root aneurysm. One patient required an operation for mitral valve

Table 4. Midterm outcomes (n = 70)

Variable	n (%)*
Follow-up period, mo	60–95
Overall death	21 (30)
Cardiac causes	5 (7)
Intraoperative	1 (1)
CHF	2 (3)
Severe AS	1 (1)
Infective endocarditis	1 (1)
Noncardiac	16 (23)
Cancer	6 (9)
Pneumonia	3 (4)
Sepsis	2 (3)
Stroke	2 (3)
ILD	1 (1)
Multisystem organ failure	1 (1)
Trauma	1 (1)
Death at 12 mo	4 (6)
Rehospitalization (cardiac-related causes)	4 (6)
CHF	2 (3)
Infective endocarditis	1 (1)
Severe AS	1 (1)
Rehospitalization, mo postoperative)	
4	1 (1)
36	1 (1)
60	2 (3)
Patients with POAF still in AF	3 (4)
Lung herniation	0

AF, atrial fibrillation; AS, aortic stenosis; CHF, congestive heart failure; ILD, interstitial lung disease; POAF, postoperative AF.

*Unless otherwise indicated.

replacement and tricuspid valve repair, at 37 months, and 1 patient underwent surgery for coronary artery bypass grafting, at 32 months. No vascular injury or seromas occurred at the site of peripheral cannulation. In cases in which the rib was shingled, to improve exposure, it was reattached, using stainless wire, at the conclusion of the operation. At the latest follow-up assessment, no lung herniation had occurred for this patient cohort. The midterm patient-related outcomes are summarized in Table 4.

Valve-related outcomes. Excluding the 1 intraoperative death, at the latest follow-up assessment, 61 patients had either no or trivial PVL, 6 had mild PVL, and 2 had moderate PVL. The latter occurred in 2 patients who had received a sutureless valve; notably, neither of them had developed endocarditis. The average for the mean transvalvular pressure gradient was 12.11 ± 9.15 mm Hg. In addition to the patient with infective endocarditis that affected the prosthetic valve, 1 patient had developed prosthetic valve thrombosis at 60 months and declined reintervention. The prosthetic valve functioning was normal in 66 patients. Figure 2, A and B shows the comparison between baseline and follow-up echocardiography findings for the degree of PVL and the mean transvalvular pressure gradients, respectively. All deaths occurred in patients who had received a Perceval valve. Figure 2C shows the number of deaths, according to the size of the prosthetic used.

Discussion

Conventional SAVR, performed via an FS, has been established to have excellent long-term outcomes.[1,30] Over the past 2 decades, TAVR has emerged as an alternative, with particular benefit for higher-risk cohorts.[31,32] TAVR valves, however, continue to be associated with a higher incidence of PVL, which is associated with adverse long-term outcomes.[33,34] TAVR also is associated with a higher rate of permanent pacemaker implantation,[35] which can increase all-cause mortality significantly.[36] An alternative to FS SAVR and TAVR is RAMT AVR. As compared to FS SAVR, RAMT can result in acceptable outcomes, including lower rates of stroke.[11] Although these and other studies have shown the excellent short-term outcomes of RAMT AVR,[37] only a paucity of data has been collected on the mid- and long-term results of RAMT AVR.

In our analysis, we report the midterm outcomes of isolated, first-time RAMT AVR from a single, consecutive cohort of patients. A total of 70 patients were followed over a period of 60-95 months. We chose to report the outcomes for this cohort, as all these patients were managed similarly postoperatively, whereas the subsequent patients underwent an enhanced recovery-after-surgery protocol at our centre. Excluding 1 intraoperative death, 50 patients were alive at the latest follow-up assessment, resulting in a 71.43% survival rate at 7 years. The rate of cardiac-related mortality was 7.14% at the 7-year follow-up assessment. Furthermore, the all-cause mortality rate in patients aged < 70 years was 4.29%. In the same age group, only 1 death had occurred from all causes, at 12 months. In the recent report by Thourani and colleagues, published as a benchmark demonstrating excellent outcomes for a large cohort of AVR patients in the Society of Thoracic Surgeons database, the overall Kaplan–Meier time-to-event analysis for all-cause mortality at 8 years was 12.4%.[1]

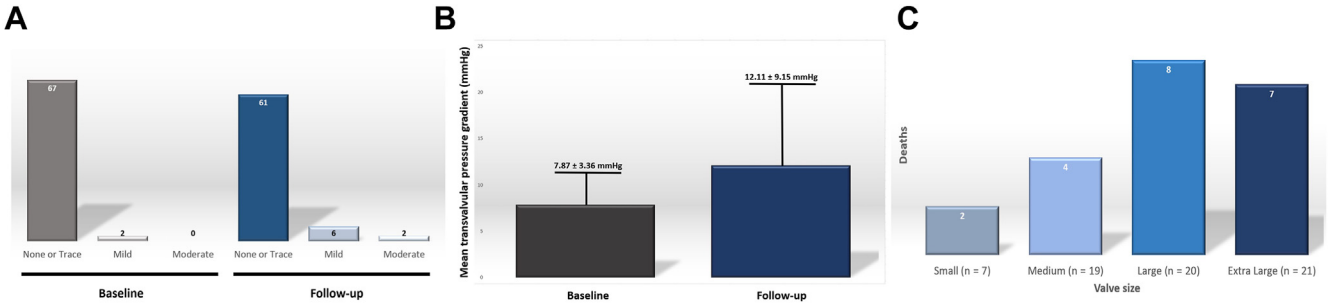

Figure 2. (**A**) Comparison between baseline and follow-up echocardiography findings for degree of paravalvular leak; (**B**) comparison between baseline and follow-up mean transvalvular pressure gradients; and (**C**) number of deaths according to size of prosthetic used.

The Thourani study included 42,586 patients for whom the mean age was 74.3 ± 5.7 years, and the mean Society of Thoracic Surgeons Predicted Risk of Mortality score was 1.9% ± 0.8%. In our work, the mean age was 73.57 ± 10.03 years, and the EuroSCORE II was 1.88% ± 1.31%, suggesting a slightly wider spread in age and risk of mortality. Further evidence that is supportive of RAMT AVR is that, at last follow-up assessment, only 3 patients in our study (4.29%) were in atrial fibrillation.

In the Placement of Aortic Transcatheter Valves (PARTNER) study, the cumulative incidence of rehospitalization due to the composite of heart failure, and valve-related or procedure-related causes after AVR, was 9.7% at 1 year.[38] However, at our centre, only 1 patient (1.42%) required rehospitalization for cardiac- or valve-related reasons within 12 months after undergoing RAMT AVR. The long-term durability of SAVR bioprostheses has been established.[39-41] In a large cohort of 12,569 patients with a Carpentier-Edwards valve, the reoperation rate was 1.9% and 15%, at 10 and 20 years, respectively.[39] With the Perceval valve, a recent meta-analysis of 3196 patients found that the aggregated survival rate at 5 years was 79.5%, the severe PVL rate was 1.6%, the structural valve deterioration rate was 1.5%, the endocarditis rate was 1.6%, and the valve explant rate was 2.3%.[42] In our cohort, 67 patients received a Perceval valve, but only 1 patient required reintervention on their aortic valve, which was indicated because of a dissection in the aortic root. At last follow-up assessment, no patients required valve explant, and no echocardiographic evidence was present of severe PVL or a significant increase in the mean transvalvular pressure gradient. Also important to acknowledge is the cross-clamp time in our series. Given that the majority of implanted valves were sutureless valves, the operative times should be lower; however, this case series comprises the first 70 consecutive RAMT AVR cases performed at our centre. We believe that the learning curve associated with performance of this technique may have contributed to the slightly longer operative times. Moreover, the length of hospital stay in this series is comparable to the duration that is often associated with conventional SAVR. Notably, this series comprises the first cases of patients undergoing minimally invasive cardiac surgery at our site, and so an enhanced recovery program had not been instituted for these patients.

Although our study provides important insight into the midterm outcomes of RAMT AVR, it does have limitations. First, this study is of a single centre, and it reports the surgical outcomes of only 2 surgeons. An essential future step is to see whether our findings can be replicated at other sites that have a high volume of RAMT AVR cases. Second, this study is retrospective. Prospective studies, also collecting data on patient-reported outcomes, should be performed. Ideally, such studies should aim to enroll patients who are undergoing FS AVR, RAMT AVR, and TAVR. Finally, the vast majority of patients in this case series received a Perceval valve. An important study for the future is to observe the long-term RAMT outcomes that occur with other types of prosthetic valves.

Conclusion

The gold-standard treatment for severe aortic stenosis has been a full median sternotomy. Over the past 2 decades, use of the alternative RAMT approach for AVR has become more common, but adoption rates of this strategy remain low. In the present study, for the first time, we report the midterm outcomes of RAMT AVR at a high-volume tertiary-care centre. We show that the RAMT approach can produce favourable results. Future work should compare the midterm and long-term outcomes of RAMT to those of conventional SAVR and TAVR.

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Ethics Statement

This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary (Ethics ID: REB18-0042).

Patient Consent

This is a retrospective study using deidentified data. Thus, the institutional research board did not require consent from the patients.

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Disclosures

The authors have no conflicts of interest to disclose.

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