Heart, Lung and Circulation (2019) **28,** 320–326
1443-9506/04/$36.00
https://doi.org/10.1016/j.hlc.2017.11.012

ORIGINAL ARTICLE

Minimally Invasive Aortic Valve Replacement Via Right Anterior Mini-Thoracotomy: Propensity Matched Initial Experience

Michael Seitz, BMedSc, MBBS [a*], Joshua Goldblatt, MBBS [a], Eldho Paul, MSc [b], Thomas Marcus, MBBS [c], Marco Larobina, MBBS, FRACS, FCSAN [d], Cheng-Hon Yap, MBBS, MS, FRACS [c]

[a]Department of Cardiothoracic Surgery, The Alfred Hospital, Melbourne, Vic, Australia
[b]Department of Epidemiology and Preventive Medicine, School of Public Health and Preventive Medicine, Monash University & Clinical Haematology Department, Alfred Hospital, Melbourne, Vic, Australia
[c]Department of Cardiothoracic Surgery, Geelong Hospital, Geelong, Vic, Australia
[d]Department of Cardiothoracic Surgery, Royal Melbourne Hospital, Melbourne, Vic, Australia

Received 5 May 2017; received in revised form 11 November 2017; accepted 14 November 2017; online published-ahead-of-print 7 December 2017

Background Aortic valve replacement by way of a right anterior mini-thoracotomy (RAMT) has shown excellent results in terms of mortality and morbidity. The aim of the present study was to compare RAMT aortic valve replacement (AVR) with conventional full sternotomy in regards to early perioperative outcomes and mortality.

Methods This was a retrospective, observational, cohort study of prospectively collected data from patients who underwent isolated, first time AVR between January 2013 and October 2016. Fifty-three RAMT patients were matched to a control group (conventional full sternotomy) using propensity score analysis.

Results The characteristics of the two cohorts were similar. The in-hospital mortality was 1.9% utilising the RAMT approach versus 5.7% using the sternotomy approach ($p = 0.34$). Ventilation times were similar in both groups (7 [5-2] vs 8 [5-13] hrs; p = 0.61). However, ICU length of stay was significantly longer in the RAMT group (median, 46.5 [23-59.5] vs 20 [14-23] hrs; $p < 0.001$), which translated into a significantly longer postoperative hospital length of stay for the RAMT group (median, 8 [6-12] vs 6 [5.5-9.5] days; $p = 0.04$) compared to the sternotomy group. RAMT was associated with a trend towards a higher incidence of postoperative AF in comparison to the sternotomy group, although this was not statistically significant (41.5% vs 28.3%; $p = 0.17$). Patients in the RAMT group had lower 4-hour chest drain output (102.5 vs 1141 ml; $p = 0.0.07$). There was no statistically significant difference in rates of non-red cell transfusions between the two groups, (17%vs28.3%; $p = 0.10$). The occurrence of stroke, re-exploration for bleeding, red-cell transfusion and wound infection was similar in both groups.

Conclusions Right anterior mini-thoracotomy in patients undergoing isolated aortic valve surgery is a safe approach in select patients, although associated with longer cardiopulmonary bypass times and ICU length of stay.

Keywords Right anterior mini-thoracotomy • Aortic valve replacement

Abbreviations: RAMT, Right Anterior Mini-Thoracotomy; ICU, Intensive Care Unit; AVR, Aortic Valve Replacement; LOS, Length of Stay; AF, Atrial Fibrillation; LV, Left Ventricle

*Corresponding author at: The Alfred Hospital, 55 Commercial Rd, Melbourne, Vic 3004, Australia., Email: seitzmj@gmail.com

Background

The number of patients presenting with degenerative aortic valve disease is still rising, primarily due to an ageing population, such that in patients over the age of 65 years, 2 to 7% have aortic valve stenosis requiring intervention [1–6]. Surgical aortic valve replacement (AVR) remains the gold standard and the only solution that can remove the underlying pathology.

Despite ongoing technical refinements, a traditional median sternotomy carries considerable iatrogenic burden [4,7–9].

Many reports, including prospective randomised-controlled trials and meta-analyses have demonstrated advantages of minimally invasive aortic valve replacements [6,10–18]. The available data is, however, mainly focussed on hemi sternotomy approaches, and only a few studies have evaluated the right anterior mini-thoracotomy (RAMT) approach. The advantages of a RAMT approach include favourable results in terms of mortality and postoperative complications, such as a lower incidence of atrial fibrillation (AF), fewer blood transfusions, shorter mechanical ventilation times, and a shorter postoperative length of stay [6,10–18]. However, the RAMT approach has been shown to have longer cardiopulmonary bypass and cross clamp times, implying that surgical exposure and the implantation of the prosthetic valves is more challenging using the RAMT approach in comparison to the conventional approach [14,19]. This is of particular concern in elderly and high risk patients, as both cardiopulmonary bypass and cross clamp times are well known independent risk factors for adverse outcomes [20].

Despite the described advantages of minimally invasive approaches, the real world uptake has been slow. In the USA and Europe, only 5 to 10% of isolated AVR operations are performed using a minimally invasive approach [11,21,22]. Of those, the number of hemi sternotomies far outweighs the RAMT approach. The reasons for this surgical reluctance are multifactorial. They include a lack of established training programs, the perception that success with the technique is limited to more proficient surgeons and a fear of deleterious patient outcomes, especially during the learning curve, as well as early studies showing difficulties in air removal, inadequate mediastinal and pleural drainage, increased risk of paravalvular leak and higher reoperation rates [23,24].

There are no guidelines with regard to which patients would benefit from RAMT AVR. The objective of this study was to compare the experience of several Victorian centres' early outcomes for RAMT versus a propensity-matched cohort of conventional sternotomy AVRs within the same institutions.

To our knowledge, this is the first Australian paper that has been written about the RAMT approach to AVR.

Methods

This was a retrospective, observational, cohort study of prospectively collected data from patients who underwent isolated, first time AVR either by conventional sternotomy or RAMT between January 2013 and October 2016 by six different surgeons. The surgeons work at three different institutions in Victoria, specifically the Royal Melbourne Hospital, the Alfred and Geelong Hospitals. To reduce the effect of treatment selection bias and potential confounding in the present observational study, we performed a propensity score-matched analysis. Thus, 53 patients undergoing AVR by a RAMT were matched to 53 patients undergoing AVR by a sternotomy (control).

Data Collection

All data was prospectively collected as part of The Australian & New Zealand Society of Cardiac & Thoracic Surgeons (ANZSCTS) database project. This is an Australia-wide data collection project of cardiac surgery procedures with mandatory participation of all government-funded adult cardiac surgical institutions. The participating institutions in this study were the Royal Melbourne Hospital, the Alfred Hospital and Geelong Hospital. The ANZSCTS database contains detailed information on patient demographics, preoperative risk factors, operative details, postoperative inpatient course, and morbidity and mortality outcomes. The institutional review board of each participating hospital had previously approved the use of these databases for research and hence, the need for individual patient consent was waived for this study.

Outcome Measures

The primary outcome for this study was 30-day mortality. Secondary outcomes were cardiopulmonary bypass, cross-clamp, and mechanical ventilation times, as well as postoperative intensive care unit (ICU) and hospital length of stay, red cell and non-red cell transfusions, and wound infection rates.

Patient Selection

Patient's suitability for RAMT was based on individual surgeon's preferences and discussion with the patient, as this is still considered a novel procedure. Essentially, all surgeons considered a patient suitable who had no history of sternotomy or thoracotomy and if a CT scan showed more than half of the ascending aorta to be on the right in respect to the right sternal border at the level of the main pulmonary artery, and the distance from the ascending aorta to the sternum less than 10 cm.

The exclusion criteria were active infective endocarditis, other minimally invasive procedures, including transcatheter aortic valve implantation (TAVI) and hemi sternotomy, patients who required concomitant procedures, previous cardiac or thoracic surgery, aortic root dilation, or those who were planned to have aortic valve repair.

Surgical Techniques

Various techniques were used for the RAMT AVR by the six participating surgeons. In brief, a mini thoracotomy was performed through a 5 to 7 cm skin incision placed at the

level of the second or third intercostal space without rib resection or dislocation of the joint. The aorta and the right atrial appendage were either directly cannulated or cardiopulmonary bypass was established peripherally using Seldinger technique under transoesophageal echocardiographic guidance (details described in results section). After vacuum-assisted cardiopulmonary bypass was established, a left ventricular vent was placed through the right superior pulmonary vein. The ascending aorta was either cross-clamped directly through the thoracotomy with a flexible angulated or Cosgrove cross-clamp or alternatively a Chitwood clamp was used via a separate stab incision. Myocardial protection was achieved with combined root, direct coronary anterograde and/or retrograde cardioplegia (details described in results section). In all RAMT cases, the surgical field was flooded with carbon dioxide at a flow of 0.5 L/min. Once the heart arrested, the aortic valve was exposed through an oblique or transverse aortotomy, the native valve removed and the annulus decalcified. The valve implantation was then performed in the supra-annular position.

In the control group, conventional AVR was performed using a median sternotomy, and cardiopulmonary bypass was instituted with the use of ascending aortic cannulation and two-stage venous cannulation of the right atrium. The left side of the heart was vented through the right superior pulmonary vein. Myocardial protection was obtained with combined anterograde and retrograde warm blood cardioplegia solution.

Postoperatively, no fast track methods or techniques were in place for either group. Conventional ICU and surgical judgment and patient threshold for discharge determined the time of discharge.

Statistical Analysis

All analyses were performed using the Stata software version 14 (StataCorp, College Station, Texas, USA) or SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were summarised using mean ± standard deviation or medians and inter-quartile ranges depending on the underlying distribution of the data. Categorical variables were reported as counts and percentages. The probability of receiving RAMT procedure was determined by a logistic regression model using age, body mass index (BMI), New York Heart Association (NYHA) and diabetes mellitus as the predictive variables. This predicted probability was used as the propensity score, and one-to-one nearest neighbouring matching was performed to select sternotomy patients, in order to reduce the effect of selection bias and potential confounding.

Baseline characteristics, intraoperative and postoperative outcomes were compared between groups (RAMT versus sternotomy AVR groups) using conditional logistic regression analyses taking into account the matched design of the study. Exact logistic regression was used when some of the cells formed by the outcome and categorical predictor variables had no observations.

All reported p-values are two-sided, and p-values of 0.05 were considered to indicate statistical significance.

Results

This was a retrospective, observational, cohort study of prospectively collected data of 434 patients with aortic valve disease who underwent primary, isolated AVR. Aortic valve replacement was performed through either RAMT (58) or full sternotomy (376) by six different surgeons, each of whom had completed less than 10 RAMT approach AVR cases. The surgeons work at three different institutions in Victoria. After performing propensity score matching, 53 patients undergoing AVR by way of RAMT were matched to 53 patients undergoing AVR by way of conventional sternotomy.

The baseline characteristics of the two cohorts are listed in Table 1. There were no significant differences between the RAMT and control groups with the exception of left ventricular ejection fraction (LVEF)3-4.

The mean age of the RAMT patient population was 73.0 ± 8.8 years, of whom 25 (47.17%) were older than 75 years, and 26 (49.06%) were female. Fifteen (28.30%) of these patients were obese with body mass indexes of over 30 kg/m^2. The mean age of the sternotomy patient population was 72 ± 11.4 years, of whom 23 (43.39%) were older than 75 years, and 28 (52.83%) were female. Fourteen (26.42%) of these patients were obese with body mass indexes of over 30 kg/m^2. Sixteen (30.19%) and 15 (28.30%) of the patients in the RAMT and sternotomy groups respectively had New York Heart Association (NYHA) class symptoms of III–IV.

Table 1 Baseline Preoperative Data for Propensity Matched Patients.

	RAMT (n = 53)	Sternotomy (n = 53)	p value
Age	73.0 ± 8.8	72.0 ± 11.6	0.50
Female Gender	26 (49.1%)	28 (52.8%)	0.73
BMI	28.0 ± 5.6	27.4 ± 4.7	0.43
BMI > 30	15 (28.3%)	14 (26.4%)	0.80
Ex-Smoker	27 (50.9%)	28 (52.8%)	0.85
Current Smoker	5 (9.4%)	6 (11.3%)	0.71
Hypertension	35 (66.0%)	27 (50.9%)	0.11
NYHA III-IV	16 (30.2%)	15 (28.3%)	0.78
LVEF 3-4	4 (7.5%)	2 (3.8%)	0.42
Diabetes	10 (18.9%)	9 (17.0%)	0.76

Data are presented as mean ± standard deviation or number (%) wherever appropriate. P values are from conditional logistic regression analyses.

Abbreviations: BMI: body mass index; NYHA: New York Heart Association; LVEF: left ventricular ejection fraction; RAMT: right anterior mini-thoracotomy.

Table 2 Intraoperative Outcomes for Propensity Matched Patients.

	RAMT (n = 53)	Sternotomy (n = 53)	p value
CPB (min)	112 (89–133)	98 (86–111)	0.08
XC (min)	76 (62–97)	76 (70–87)	0.52
Conversion	3 (5.7%)	–	–
Valve Size (mm)	22.6 ± 2.3	21.9 ± 2.3	0.44
Mechanical	3 (5.7%)	12 (22.6%)	0.028
Bioprosthesis	50 (94.3%)	41 (77.4%)	0.028
Central Arterial Cannulation	9 (17.0%)	53 (100%)	<0.0001

Data are presented as mean ± standard deviation, median and interquartile range (p25-p75) or number (%) wherever appropriate. P values are from conditional logistic regression analyses.

Abbreviations: RAMT: right anterior mini-thoracotomy; CPB: cardiopulmonary bypass; XC: cross-clamp.

Left ventricular ejection fraction (LVEF) was categorised as 1 (normal >60%), 2 (mild impairment 46 to 60%), 3 (moderate impairment 35 to 45%) and 4 (severe <30%). In the RAMT and sternotomy groups, four and two patients respectively had a moderately or severely impaired left ventricular function (p = 0.42).

Twenty-seven (50.94%) and 28 (52.83%) were ex-smokers, and five (7.94%) and six (11.32%) were current smokers in the RAMT and sternotomy groups, respectively. Thirty-five (66.04%) and 27 (50.94%) patients had diagnosed hypertension in the RAMT and sternotomy groups, respectively (Table 2).

In the RAMT group, 49 (92.45%) patients had aortic stenosis, one of which was rheumatic, 11 were bicuspid and 37 idiopathic calcific in nature. Of these, 27 (50.94%) had mixed stenosis and regurgitation. Four patients had isolated aortic regurgitation. In the sternotomy group, 51 (96.23%) patients had aortic stenosis, of which one was rheumatic, nine were bicuspid, and 41 idiopathic calcific in nature. Of these, 43 (81.13%) had mixed stenosis and regurgitation. Two patients had isolated aortic regurgitation.

Examination of intraoperative variables revealed that patients in the RAMT group had slightly longer cardiopulmonary bypass times (112 vs 98 min, $p = 0.08$), but equivalent cross-clamp time (76 vs 76 min; $p = 0.52$), as shown in Table 2.

In the RAMT group, three mechanical and 50 biological aortic prostheses were implanted, whereas 12 mechanical and 41 biological aortic prostheses were implanted in the sternotomy group. Mean diameter of the aortic valve prosthesis was 22.61 ± 2.23 mm in the RAMT group, and 21.92 ± 2.23 mm in the sternotomy group ($p = 0.44$). In the RAMT group, 16 sutureless valves were deployed of which two were size XL, nine were L, two were M and one was S. No sutureless valves were used in the sternotomy group.

Three of 53 patients required intraoperative conversion from RAMT to full sternotomy (5.66%): one due to severe pleural adhesions, one due to difficult exposure and one due to uncontrollable bleeding.

Nine (16.98%) of the RAMT approach patients had central aortic cannulation, the remaining 44 (83.02%) had peripheral femoral cannulation. All sternotomy patients had central cannulation.

Examination of postoperative variables revealed that there was no significant difference in the primary outcome, 30-day mortality, between the two groups. Thirty-day mortality was 1.89% (1/53) utilising the RAMT approach versus 5.66% (3/53) using the sternotomy approach ($p = 0.34$).

There was no statistically significant difference in mechanical ventilation times between the two groups (median, 7 [5–12] vs 8 [5.5-13.5]; $p = 61$).

Unexpectedly, patients in the RAMT group had a significantly longer ICU length of stay than the patients in the sternotomy group (median, 46.5 hours [23-59.5] vs 20 hours [15–23]; $p < 0.0001$). This translated into a significantly longer postoperative hospital length of stay for the RAMT group (median, 8 days [6–12] vs 6 days [5.5-9.5]; $p = 0.042$) compared to the sternotomy group. This unexpected result was verified, by comparing all unmatched sternotomy patients against RAMT patients, and the difference in hospital length of stay remained, however it did not reach statistical significance (median, 8 days [6–12] vs 7 days [6–10]; $p = 0.11$).

Right anterior mini-thoracotomy was associated with a trend towards a higher incidence of postoperative AF in comparison to the sternotomy group, although this was not statistically significant (22 [41.51%] vs 15 [28.30%]; $p = 0.074$).

Patients in the RAMT group had lower 4-hour chest drain output (130.66 millilitres ± 121.63 vs 183.77 millilitres ± 128.33; $p = 0.205$). This was not associated with a statistically significant difference in the incidence of non-red cell transfusions between the two groups (9 units [16.98%] and 15 units [28.30%]; $p = 0.10$). The incidence of red cell transfusion was equal in both groups (14 packs [26.4%] and 14 packs [26.4%]; $p = 1.0$), with a mean use of red blood cells of 1.72 ± 2.57 packs in the RAMT group vs 1.89 ± 1.09 packs in the sternotomy group.

The incidence of re-exploration for bleeding was 5.66% (3) in the RAMT group and 7.55% (4) in the sternotomy group; $p = 0.322$ In the RAMT group, the bleeding was in two cases related to subcostal bleeding and one case from the suture line of the aortotomy.

One patient in the sternotomy group had stroke in comparison to no strokes in the RAMT group.

The occurrence of re-intubation, pneumonia and wound infection was low and similar in both groups, as shown in Table 3.

Discussion

This retrospective, propensity-matched study shows that minimally invasive AVR using a RAMT approach is a safe and reproducible procedure associated with a low postoperative 30-day mortality and morbidity, comparable to that of

Table 3 Postoperative Outcomes for Propensity Matched Patients.

	RAMT (p = 53)	Sternotomy (p = 53)	p value
30-Day Mortality	1 (1.9%)	3 (5.7%)	0.34
4hr ICC Output (ml)	102.5 (52.5–161)	141 (100–220.5)	0.072
Mechanical Ventilation (hrs)	7 (5–12)	8 (5–13)	0.61
Red Cell Transfusion	14 (26.4%)	14 (26.4%)	1.0
Non-Red Cell Transfusion	9 (17.0%)	15 (28.3%)	0.10
ICU LOS (hrs)	46.5 (23–59.5)	20 (14–23)	<0.001
Hospital LOS (days)	8 (6–12)	6 (5.5–9.5)	0.04
New Onset AF	22 (41.5%)	15 (28.3%)	0.17
CVA	0 (0%)	1 (1.9%)	1.0
Re-Intubation	2 (3.8%)	1 (1.9%)	1.0
Pneumonia	1 (1.9%)	2 (3.8%)	1.0
Return to Theatre for Bleeding	3 (5.7%)	4 (7.6%)	0.66
Wound Infection	0 (0%)	0 (0%)	1.0

Data are presented as median and interquartile range (p25-p75) or number (%) wherever appropriate. P values are from conditional logistic regression analyses. Abbreviations: RAMT: right anterior mini-thoracotomy; ICC: intensive cardiac care; ICU: intensive care unit; LOS: length of stay; AF: atrial fibrillation; CVA: cerebrovascular accident.

an AVR via a sternotomy. This represents the early experience of several surgeons with this new technique.

The Society of Thoracic Surgeon (STS) database has quoted a mortality for sternotomy AVR of 2.6% [6,25]. The primary outcome of this study, 30-day mortality, showed a trend favouring the RAMT approach (1.89%), although this difference was not significant. This is in line with many of the large studies, which showed hospital mortality rates of 1.2–1.9%, which were not different to the sternotomy mortality rates [19,23,26,27]. More recently however, a meta-analysis has shown a reduction in hospital mortality for isolated AVR utilising the RAMT approach [28].

Our study demonstrated longer cardiopulmonary bypass times, but equivalent cross-clamp times for the RAMT group, a finding consistent with most of the literature [14,19,24,27]. Aortic valve replacement via RAMT is undoubtedly more complex and technically challenging. It entails a distinct learning curve because of the deeper operative field, limited working space for the exposure and implantation of the prosthetic valve, as well as the use of new equipment and methods. A study by Murzi et al. has evaluated the learning curve of a single surgeon for this procedure and demonstrated that patients undergoing RAMT AVR are not exposed to an increased operative risk during the surgeon's initial experience [24]. Our data set is in line with the study by Murzi et al., as our data is collected from surgeons who had done less than 10 cases each and are therefore at the very beginning of their learning curve. Despite this, our data demonstrates safety of the procedure. This should encourage further adaptation and use of the RAMT approach. In the elderly and high risk population however, a longer cardiopulmonary bypass and cross-clamp time is of particular concern as they are well-known independent risk factors for adverse outcomes [20]. This should be taken into consideration in the patient selection in the initial phase of RAMT approach AVRs.

We found that patients undergoing AVR by way of RAMT had similar mechanical ventilation times, but a longer ICU length of stay, the latter being statistically significant, which is not consistent with other publications. One explanation for this is that patients undergoing a new and unfamiliar procedure are treated differently to the accustomed protocol and there is reluctance to discharge these patients to the ward early on. Publications elsewhere by groups who have been using the RAMT approach for many years, clearly show shorter ventilation times as well as shorter ICU length of stay [6,10–18]. One paper described that shorter ICU length of stay translated into earlier discharges with a higher proportion of patients going directly home, which significantly lowered health care costs [29].

Limited heart manipulation and trauma is associated with a reduction in the incidence of postoperative atrial fibrillation [30]. Previous studies have reported mixed results on the incidence of AF following RAMT AVR. Some report that the incidence of postoperative AF is unchanged, while others report reduced incidences of AF following RAMT AVR [14,18,19,28,31,32]. Our study demonstrated a trend to higher rates of AF after RAMT AVR.

Since the introduction of RAMT AVR, a reduction in bleeding, blood transfusions and re-explorations was expected. However, both observational and randomised studies have demonstrated conflicting results. Most demonstrated less bleeding using a RAMT approach, with a reduction in red cell unit transfusion [14,19,28,31]. In our study, the 4-hour chest drain output was lower in the RAMT group, with no difference in the rate of non-red cell transfusions or red cell transfusions. Other groups reported no differences either in the percentage of patient transfusions or in the amount of red cell and non-red cell transfusions. The incidence of re-exploration for bleeding

was 5.66% in the RAMT group, which is within the in the range cited in the literature of 1 to 7% [31,32].

The cerebrovascular event rate during isolated sternotomy AVR is approximately 1.4% [25]. Early studies had suggested that RAMT AVRs are associated with a higher incidence of postoperative cerebrovascular events [33]. Subsequent studies however, have shown equivalent low rates of cerebrovascular events (1.6%), which was confirmed by a meta-analysis [26,28,33]. One incidence of stroke was recorded in the sternotomy group and no neurologic events were encountered in the RAMT group. In our study the vast majority of patients underwent peripheral femoral arterial cannulation, similar to what is described by most papers. Peripheral arterial cannulation itself is associated with wound infections, pseudoaneurysms and neurological events [18]. When using retrograde perfusion, the atherosclerotic burden in the aortic arch and descending aorta seem to play a crucial role in the incidence of postoperative cerebrovascular accident (CVA), especially in elderly patients. Retrograde perfusion was identified to be the only independent risk factor for stroke [22,34]. In order to avoid these complications, cannulation of the ascending aorta should be the preferential approach, which allows a more direct and physiological flow, and retrograde perfusion may be a viable option for younger patients without vascular disease.

Wound infections are another topic of great importance evaluated by the literature, in view of its serious consequences, including death by mediastinitis associated with deep sternal wound infections. Neither group in our series had a wound infection, but our sample size is too small to demonstrate a meaningful difference in a low incidence event, such as wound infection. A recent meta-analysis however, has demonstrated a significant benefit from RAMT AVR approach over sternotomy approach in terms of wound infection [28,32].

This study has several limitations. Firstly, this is a retrospective analysis, with all the limitations that may entail. Secondly, selecting a patient for RAMT approach was dependent on the anatomical position of the ascending aorta but, ultimately, on surgeon preferences. That results in a selection bias, which we tried to account for by propensity matching. The surgical set-up for the RAMT approach is different for every surgeon, specifically with respect to cannulation and cardioplegia strategies. Thirdly, the number of patients undergoing RAMT approach AVR was limited because it was the initial experience with this surgical approach, so the number of patients in this study is too low to draw meaningful conclusions, but rather it is meant to demonstrate safety during the early phase of experience. Lastly, as the control cases for propensity-matching were drawn from a larger cohort (ANZSCTS database), this represents a potential weakness of the comparison as cases were not specifically matched to controls from the same hospital.

Unfortunately, echocardiographic data was not available for this population, which will require further analysis in the future. This data is especially important when comparing RAMT AVR to TAVI, which is still associated with a significant incidence of paravalvular leak and no long-term durability data.

Conclusion

Minimally invasive surgical techniques represent a significant paradigm shift in the treatment of aortic valve disease. A number of publications have demonstrated that the short-term results of the RAMT technique are at least as good as, if not better than conventional aortic valve replacement performed through the standard median sternotomy [13,18,24].

Exposure and implantation of a valve using the RAMT approach is clearly more challenging, as shown by longer cardiopulmonary bypass and cross-clamp times. This is an important finding, as the introduction of a rapid deployment and sutureless valves may facilitate the reduction in cardiopulmonary bypass and cross-clamp times. However, the adoption of such technologies remains limited to a few centres as long-term results are not yet known for these devices [14,17].

Currently, up to 40% of patients over the age of 70 are denied aortic valve surgery, based on their age and risk profile [35]. Advances in TAVI have provided an alternative for these patients, however surgical AVR via a RAMT is a very competitive alternative in high risk, elderly, frail and obese patients. Cardiac surgeons must pursue and perform minimally invasive aortic surgery as a true alternative for minimal invasive approaches.

Although RAMT still represents a small proportion of the total caseload in Australia, it represents a shift in the approach to aortic valve surgery. According to our study and others, RAMT AVR can be safely implemented in select patients as a routine cardiac surgery procedure, although the operative times are significantly longer. The early postoperative outcome was equal to that of the sternotomy approach. Once proficiency is acquired, this minimal access approach may be the procedure of choice for AVR and a genuine alternative to transaortic valve replacement (TAVR) in high risk patients. However, a randomised trial is required to confirm this hypothesis.

Acknowledgements

Disclosures: Authors have nothing to disclose with regard to commercial support.

References

[1] Carabello BA, Paulus WJ. Aortic stenosis. Lancet 2009;373:956–66.
[2] Gilmanov D, Farneti PA, Ferrarini M, Santarelli F, Murzi M, Miceli A, et al. Full sternotomy versus right anterior minithoracotomy for isolated aortic valve replacement in octogenarians: a propensity-matched study. Interact Cardiovasc Thorac Surg 2015;20:732–41.
[3] Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, Guyton RA, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;63.

[4] Lamelas J. Minimally invasive aortic valve replacement: the ''Miami Method''. Ann Cardiothorac Surg 2015;4:71–7.
[5] Stewart BF, Siscovick D, Lind BK, Gardin JM, Gottdiener JS, Smith VE, et al. Clinical factors associated with calcific aortic valve disease. Cardiovascular Health Study. J Am Coll Cardiol 1997;29:630–4.
[6] Glauber M, Ferrarini M, Miceli A. Minimally invasive aortic valve surgery: state of the art and future directions. Ann Cardiothorac Surg 2015;4 (1):26–32.
[7] Walther T, Blumenstein J, van Linden A, Kempfert J. Contemporary management of aortic stenosis: surgical aortic valve replacement remains the gold standard. Heart 2012;98(Suppl. 4):iv23–9.
[8] Fattouch K, Moscarelli M, Del Giglio M, Albertini A, Comoglio C, Coppola R, et al. Non-sutureless minimally invasive aortic valve replacement: mini-sternotomy versus mini-thoracotomy: a series of 1130 patients. Interac Cardiovasc Thorac Surg 2016;23:253–8.
[9] Ghanta Ravi K, Lapar Damien J, Kern John A, Kron Irving L, Speir Allen M, Fonner Jr wn, et al. Minimally invasive aortic valve replacement provides equivalent outcomes at reduced cost compared with conventional aortic valve replacement: a real-world multi-institutional analysis. J Thorac Cardiovasc Surg 2015;149:1060–5.
[10] Brown ML, McKellar SH, Sundt TM, Schaff HV. Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis. J Thorac Cardiovasc Surg 2009;137:670–9. e5.
[11] Attia RQ, Hickey GL, Grant SW, Bridgewater B, Roxburgh JC, Kumar P, et al. Minimally invasive versus conventional aortic valve replacement: a propensity-matched study from the UK National Data. Innovations (Phila) 2016;11:15–23.
[12] Murtuza B, Pepper JR, DeL Stanbridge R, Jones C, Rao C, Darzi A, et al. Minimal access aortic valve replacement: is it worth it? Ann Thorac Surg 2008;85:1121–31.
[13] Brinkman WT, Hoffman W, Dewey TM, Culica D, Prince SL, Herbert MA, et al. Aortic valve replacement surgery: comparison of outcomes in matched sternotomy and PORT ACCESS groups. Ann Thorac Surg 2010;90:131–5.
[14] Miceli A, Murzi M, Gilmanov D, Fugà R, Ferrarini M, Solinas M, et al. Minimally invasive aortic valve replacement using right minithoracotomy is associated with better outcomes than ministernotomy. J Thorac Cardiovasc Surg 2014;148:133–7.
[15] Murtuza B, Pepper JR, Del Stanbridge R, Jones C, Rao C, Darzi A, et al. Minimal access aortic valve replacement: is it worth it? Ann Thorac Surg 2008;85:1121–31.
[16] Tabata M, Umakanthan R, Cohn LH, Bolman RM, Shekar PS, Chen FY, et al. Early and late outcomes of 1000 minimally invasive aortic valve operations. Eur J Cardiothorac Surg 2008;33:537–41.
[17] Gilmanov D, Miceli A, Bevilacqua S, Farneti P, Solinas M, Ferrarini M, et al. Sutureless implantation of the perceval s aortic valve prosthesis through right anterior minithoracotomy. Ann Thorac Surg 2013;96:2101–8.
[18] Ruttmann E, Gilhofer TS, Ulmer H, Chevtchik O, Kocher A, Schistek R, et al. Propensity score-matched analysis of aortic valve replacement by mini-thoracotomy. J Heart Valve Dis 2010;19:606–14.
[19] 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.
[20] Al-Sarraf N, Thalib L, Hughes A, Houlihan M, Tolan M, Young V, et al. Cross-clamp time is an independent predictor of mortality and morbidity in low- and high-risk cardiac patients. Int J Surg 2011;9:104–9.
[21] Kempfert J, Mohr FW, Walther T. Minimally invasive aortic valve surgery: where now and where to next? Expert Rev Cardiovasc Ther 2009;7:451–3.
[22] Modi P, Hassan A, Chitwood WR. Minimally invasive mitral valve surgery: a systematic review and meta-analysis. Eur J Cardiothorac Surg 2008;34:943–52.
[23] Mikus E, Turci S, Calvi S, Ricci M, Dozza L, Del Giglio M. Aortic valve replacement through right minithoracotomy: is it really biologically minimally invasive? Ann Thorac Surg 2015;99:826–30.
[24] Murzi M, Cerillo AG, Bevilacqua S, Gilmanov D, Farneti P, Glauber M. Traversing the learning curve in minimally invasive heart valve surgery: a cumulative analysis of an individual surgeon's experience with a right minithoracotomy approach for aortic valve replacement. Eur J Cardiothorac Surg 2012;41:1242–6.
[25] Brown JM, O'Brien SM, Wu C, Sikora JAH, Griffith BP, Gammie JS. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: changes in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. J Thorac Cardiovasc Surg 2009;137:82–90.
[26] Glower DD, Lee T, Desai B. Aortic valve replacement through right minithoracotomy in 306 consecutive patients. Innov Technol Tech Cardiothorac Vasc Surg 2010;5:326–30.
[27] Ferreira RTR, e Silva RR, Marchi E. Aortic valve replacement: treatment by sternotomy versus minimally invasive approach. Braz J Cardiovasc Surg 2016;31:422–7.
[28] Phan K, Adv BS, Xie A, Di Eusanio M, Yan TD. A meta-analysis of minimally invasive versus conventional sternotomy for aortic valve replacement. Ann Thorac Surg 2014;98:1499–511.
[29] Ghanta RK, Lapar DJ, Kern JA, Kron IL, Speir AM, Fonner E, et al. Minimally invasive aortic valve replacement provides equivalent outcomes at reduced cost compared with conventional aortic valve replacement: a real-world multi-institutional analysis. J Thorac Cardiovasc Surg 2015;149:1060–5.
[30] Mariscalco G, Engström KG. Atrial fibrillation after cardiac surgery: risk factors and their temporal relationship in prophylactic drug strategy decision. Int J Cardiol 2008;129:354–62.
[31] 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.
[32] Mariscalco G, Musumeci F. The minithoracotomy approach: a safe and effective alternative for heart valve surgery. Ann Thorac Surg 2014;97:356–64.
[33] Gammie JS, Zhao Y, Peterson ED, O'Brien SM, Rankin JS, Griffith BPJ. Maxwell Chamberlain Memorial Paper for adult cardiac surgery. Less-invasive mitral valve operations: trends and outcomes from the Society of Thoracic Surgeons Adult Cardiac Surgery Database. Ann Thorac Surg 2010;90. 1401–8, 1410–10.
[34] Murzi M, Cerillo AG, Miceli A, Bevilacqua S, Kallushi E, Farneti P, et al. Antegrade and retrograde arterial perfusion strategy in minimally invasive mitral-valve surgery: a propensity score analysis on 1280 patients. Eur J Cardio Thoracic Surg 2013;43:e167–72.
[35] Bouma BJ, van den Brink RB, Zwinderman K, Cheriex EC, Hamer HH, Lie KI, et al. Which elderly patients with severe aortic stenosis benefit from surgical treatment? An aid to clinical decision making. J Heart Valve Dis 2004;13:374–81.