Comparison of outcomes between aortic root replacement and supra-coronary interposition graft for type A aortic dissection: A Retrospective Case Series

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Abstract

Background The decision to conserve or replace the native aortic valve following acute type-A aortic dissection (ATAAD) is an area of cardiac surgery without standardised practice. This single centre retrospective study analysed the long-term performance of the native aortic valve and root following surgery for ATAAD. *Methods* Between 2009 and 2018 all cases ATAAD treated at Royal Brompton and Harefield NHS Foundation Trust were analysed. Patients were divided into 2 groups: a) ascending aorta (interposition) graft (AAG) without valve replacement; and b) non-valve-sparing aortic root replacement (ARR). Pre-operative covariates were compared, as well as operative characteristics and post-operative complications. Long-term survival and echocardiographic outcomes were analysed using regression analysis. *Results* In total, 116 patients were included: 63 patients in the AAG group and 53 patients in the ARR group. In patients where the native aortic valve was conserved, 9 developed severe aortic regurgitation and 2 patients developed dilation of the aortic root requiring subsequent replacement during the follow-up period. Aortic regurgitation at presentation was not found to be associated with subsequent risk of developing severe aortic regurgitation or reintervention on the aortic valve. Overall mortality was observed to be significantly lower in patients undergoing AAG (17.5% vs. 41.5%, p=0.004). *Conclusions* With careful patient selection, the native aortic root shows good long-term durability both in terms of valve competence and stable root dimensions after surgery for ATAAD. This study supports the consideration of conservation of the aortic valve during emergency surgery for type-A dissection, in the absence of a definitive indication for root replacement, including in cases where aortic regurgitation complicates the presentation.

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Key words:

Type A aortic dissection, Aortic root replacement, Echocardiography

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Conclusions

With careful patient selection, the native aortic root shows good long-term durability both in terms of valve competence and stable root dimensions after surgery for ATAAD. This study supports the consideration of conservation of the aortic valve during emergency surgery for type-A dissection, in the absence of a definitive indication for root replacement, including in cases where aortic regurgitation complicates the presentation.

Introduction

The extent of emergency repair following acute type-A aortic dissection (ATAAD), and in particular the decision whether to conserve the native aortic valve, remains an area of cardiac surgery without standardised practice [1]. In cases of ATAAD with known connective tissue disease, extension of the intimal tear into the root or aneurysmal dilation of the ascending aorta a decision to replace the native aortic valve at the time of emergency surgery is relatively straightforward. In many cases, however, the balance between a more extensive initial operation, incorporating replacement of the native aortic valve, compared to a simpler operation preserving the aortic valve, with a possible higher risk of subsequent re-intervention, is less clear [2][3].

ATAAD typically involves an intimal tear in the ascending aorta distal to the sinotubular junction, a pathological process which is complicated by acute aortic regurgitation in approximately half of cases [3][5]. Several mechanisms have been established for regurgitation in this situation including prolapse of the dissection flap through the aortic valve or leaflet prolapse due to disruption of their attachments to the aortic wall [6].

Deciding whether to preserve the native aortic valve in cases complicated by significant aortic regurgitation is typically determined by individual surgeon preference. However, ensuring aortic valve competency is an important marker of successful ATAAD repair. Surgeons opting for valve replacement can guarantee this, at least in the short term, where the goal is to perform the safest operation that maximises the chances of patient survival. A final decision on the surgical approach to treatment of the aortic valve cannot be taken until the aorta is opened. In addition to the decision regarding replacement of the aortic valve, the surgeon is faced with several other critical operative choices which must be made in a timely manner. These include alternative bypass strategies, cerebral protection, and the need to address the aortic arch.

Despite the well-reported advantages and disadvantages of both options, the factors predicting subsequent aortic regurgitation, dilation of the aortic root and re-intervention are still poorly understood due to the lack of long-term data. This retrospective case series compares the outcomes for patients undergoing preservation of the native aortic valve at the time of emergency surgery for type-A aortic dissection with a cohort of patients where the aortic valve was replaced. In the cohort of patients where the native aortic valve was conserved the echocardiographic performance of the native aortic valve and root was analysed by follow up transthoracic echocardiography.

Methods

Study Design

All patients admitted to the Royal Brompton and Harefield NHS Foundation Trust between January 2009 and December 2018 with ATAAD and who underwent emergency surgery were identified for inclusion in this study. Perioperative data was prospectively collated with adherence to national guidelines for cardiothoracic surgery data reporting including data collection on baseline demographics, operative variables and short-term outcomes [7]. Long term mortality was assessed using the NHS Spine database [8]. The requirement for ethical approval was waived by the Research Ethics Office at Royal Brompton and Harefield NHS Foundation Trust due to the retrospective nature of the study.

Patients included in this study were divided into two cohorts determined by whether the native aortic root (including valve) was replaced or preserved at the time of emergency surgery. In the first cohort, patients undergoing aortic root replacement (ARR) had either a composite valve-graft replacement (Bentall's procedure) or porcine valve-graft replacement (Freestyle procedure). In the second cohort, patients underwent an asacending aorta interposition graft (AAG) with preservation of the aortic root and resuspension of the native aortic valve. No patients in this institution underwent valve-sparing root replacement (e.g. David/Yacoub procedures) for ATAAD. To ensure homogeneity of the cohort, all patients undergoing replacement of the arch (e.g. total arch replacement, frozen elephant trunk) were excluded from the study.

Operative Technique

The decision to proceed with AAG or ARR was based on individual surgeon preference. However, several common factors were identified at this institution as favouring root replacement over preservation of the native aortic valve. In particular; younger age, known connective tissue disease, dilation of the aortic root, moderate or severe aortic regurgitation at presentation and a dissection tear extending into the aortic root were considered variables favouring ARR.

All patients in this study underwent a median sternotomy to gain access to the mediastinum. The right subclavian artery was used as the preferred arterial cannulation site. Where this was not possible femoral artery or direct aortic cannulation were used as alternatives. Venous cannulation was routinely performed using the right atrial appendage. Following stabilisation of patients on cardio-pulmonary bypass cold-blood cardioplegia solution was given either retrograde via the coronary sinus or antegrade directly into the coronary ostia. Patients were then cooled to 18C prior to deep hypothermic circulatory arrest for inspection of the aortic arch and ascending aorta.

In patients undergoing preservation of the native aortic valve the portion of ascending aorta effected by the intimal tear was resected and replaced with an interposition graft. The aortic valve commissures were resuspended on the aortic wall using pledgeted sutures where necessary. In cases where a decision was taken to replace the native aortic valve the aortic root was excised, annulus sized and a composite valve graft sewn into the annulus using interrupted sutures. The left and right coronary buttons were then reimplanted into the graft. Where the intimal tear extended into the aortic arch a hemi-arch or total arch replacement were performed with reimplantation of the aortic branch vessels as necessary. Patients undergoing total arch replacement where excluded from inclusion in this study.

Patient follow-up

Patients in the AAG cohort were followed up initially for one month post-surgery and subsequently had annual outpatient follow up, including transthoracic echocardiography, to determine the long-term characteristics of the native aortic valve and root following ATAAD. Echocardiographic images were reviewed to determine the degree of aortic regurgitation and dimensions of the aortic root at the level of the annulus, sinus of Valsalva, sinotubular junction and ascending aorta. These parameters were compared with the initial imaging reports and any discrepancies discussed and agreed with a second reviewer.

Statistical Analysis

Pre-operative covariates were assessed for normal distribution using the Shapiro-Wilk test. Between group characteristics were assessed for statistical differences using the Student T-test or Wilcoxon Rank Test for non-parametric variables. Differences in discrete data was assessed using Pearson's χ^2 test. Multivariate logistic regression models were constructed to assess the influence of a variety of covariates on a composite end-point (moderate/severe aortic regurgitation, reintervention on the aortic root or valve and mortality).

Crude survival curves were estimated using the nonparametric Kaplan-Meier method, and log rank tests were used to compare the survival distribution among groups. Cox proportional hazard regression was conducted to calculate the adjusted hazards ratio with 95% confidence intervals. Stepwise selection was performed using age, sex, COPD, Euroscore, NYHA class and LV function in the model. Statistical analyses were conducted using the Stata 13.0 software (Stata Corp., College Station, TX, USA).

Results

A total of 116 patients met the inclusion criteria during the study period. Of these 63 patients underwent AAG and 53 underwent ARR. Of the 53 patients who had the native aortic valve and root replaced 26 had replacement using a freestyle graft and 27 had replacement using Bentall's procedure. Within the Bentall's subgroup 23 patients had a mechanical composite valve-graft and 4 patients had a tissue valve-graft. These different composite valve-grafts (ARR) have been shown to have comparable mid-term outcomes following ATAAD and are therefore considered as a single group for the purposes of analysis [9].

Table 1 compares the patient baseline demographics of the AAG and ARR cohorts. There were no significant differences between the two cohorts with respect to age, gender, co-morbidities and BMI. Table 1 also compares the operative characteristics of the AAG and ARR cohorts. These cohorts were similar with respect to pre-operative surgical risk as assessed by Euroscore II (23.4 vs. 21.9, p=0.626) and the incidence of moderate or severe aortic regurgitation on presentation (30.2% vs. 39.6%, p=0.285). A significantly longer cardiopulmonary bypass time (160 minutes vs. 211 minutes, p=0.011) and cross clamp time (101 minutes vs. 203 minutes, p<0.001) was observed in the ARR cohort.

Short term outcomes

Outcome data with respect to mortality, reintervention and complications post operatively are compared in Table 2 and Figure 1. A markedly lower mortality was observed in the aortic valve resuspension cohort at all time points during the follow up period. This difference was accounted for by the higher operative mortality observed in the ARR cohort (1.6% vs. 17%, p=0.003). The incidence of postoperative complications including return to theatre, stroke, renal failure, deep sternal wound infection and gastrointestinal bleeding was comparable in the two cohorts.

Multivariate logistic regression analysis found both root replacement (OR 35.2, 95% CI 2.4 – 522.0, p=0.01) and longer circulatory arrest time (OR 1.04, 95% CI 1.01 – 1.08, p=0.01) to be significantly associated with operative mortality (Table 3).

Data pertaining to the length of hospital stay was positively skewed. To assess the effects of pre-operative covariates on length of stay, an inverse gaussian generalised linear regression model was used, finding no association between patient/operative covariates and patient stay (p>0.05) (Table 4).

Overall Survival

Results were available for up to 10 years follow up for survival analysis (total follow up time was 578 patient years). Mean follow up time was 5.3 ± 3.6 years. Kaplan Meier analysis (Figure 2) showed improved survival throughout the 10 year period for the AAG cohort compared to the ARR patients. Ten-year survival rates were: AAG 74.6% (95% CI 55.8–86.4%), ARR 48.7% (95% CI 26.1–68.1%), Logrank test p=0.008.

Cox regression analysis identified ARR to be a predictor of worse survival compared to AAG (hazard ratio 2.54, 95% CI 1.25 – 5.15, p=0.01). In addition, advanced age was related to poorer long-term survival (HR 1.02, 95% CI 1.01 – 1.05, p=0.05). Other pre-operative covariates (e.g. Euroscore II, Diabetes, gender) or operative parameters (including cardiopulmonary bypass time) were not associated with poorer survival (p>0.05) (Table 5).

Echocardiographic follow-up

Of the surviving patients in the AAG group, 80% underwent follow-up echocardiography. Only 2 patients had moderate or severe aortic regurgitation (AR) on discharge from hospital. During the follow up period, a further 9 patients developed moderate AR and 3 patients developed severe AR. Figure 2 shows the degree of AR determined by transthoracic echocardiography, incidence of reintervention and mortality during the follow-up period. The degree of AR was assumed to be constant until a follow-up transthoracic echocardiogram showed deterioration in the function of the valve.

Table 6 shows the average growth rates of the aortic root in patients undergoing AAG following ATAAD. 2 patients met the threshold for reintervention on the aortic root based on the dimensions of the aortic root [10]. In one case the patient underwent freestyle composite valve-graft replacement of the root and valve due to an ascending aortic aneurysm with the point of maximum dilation at the level of the Sinus of Valsalva. The second patient underwent replacement of the supracoronary graft due to development of a pseudoaneurysm at the proximal suture line.

The degree of aortic regurgitation and the dimensions of the aortic root at presentation and operative variables including CPB, cross clamp and deep hypothermic circulatory arrest times did not predict reintervention on the aortic root, development of severe aortic regurgitation or death using the multivariate logistic regression analysis. Root replacement and increased circulatory arrest time was associated with operative mortality. Full statistical results are presented in appendix 1.

Discussion

This single centre retrospective case series analysed the performance of the native aortic valve and root following surgery for ATAAD. Mortality was observed to be lower in patients undergoing resuspension of the native aortic valve compared to aortic root replacement in this series. The difference in observed mortality during the follow-up period was accounted for by higher, 30-day, operative mortality in patients where the aortic valve was replaced. Although surgical risk, as assessed by Euroscore II, was comparable between the two cohorts, patients where the native aortic valve was preserved had significantly lower mortality than might be expected by pre-operative risk scoring. This is contrast to most studies, including several metanalyses, which have suggested comparable mortality between aortic valve resuspension and ARR for ATAAD [11][12].

Decision process for preserving the root

A potential confounding factor favouring better outcomes in AAG patients may be the surgeon's preference for root replacement in cases involving more extensive disease at presentation. Our experience suggests, poor aortic tissue quality, lack of aortic valve leaflet integrity and a larger aortic root are used by surgeons as subjective variables to favour replacement of the aortic root. These characteristics, which are not reflected in operative risk assessment, may have contributed to higher operative mortality in this cohort. A greater emphasis on individual surgeon familiarity with the chosen operative strategy is necessary, compared to elective cardiac surgery procedures, given the variability of ATAAD presentation and emergency nature of surgery for type A aortic dissection. In this series, the higher mortality in the ARR cohort was not reflected in increased incidence of postoperative complications.

A well-established concern with preservation of the native aortic valve following ATAAD is a possible increased risk of subsequent reintervention on the native aortic root or valve[10]. However, several surgical centres have been able to achieve low rates of surgical reintervention during long term follow up. Von. Segesser et al. and Mazzucotelli demonstrated freedom from reoperation of 91% and 80% respectively in a case series of patients undergoing valve resuspension procedures for ATAAD [13][3]. The incidence of reintervention on the aortic root or valve in this study was similarly low in both cohorts. The present study also found the dimensions of the aortic root to be realtively stable following resuspension of the native aortic valve. Only 2 patients were observed to have significant dilation of the aortic root during follow-up, both of whom underwent reintervention.

Considering valve competence

Using a supracoronary interposition graft and resuspension of the native aortic valve, has numerous potential advantages over aortic valve replacement. The approach is technically more straightforward than root replacement, the latter requiring more operative steps and technical skill, especially in the emergency setting. Additionally, in young patients who are otherwise likely to receive a mechanical valve replacement, native valve preservation avoids the risks of long term anticoagulation, including delayed false lumen thrombosis and haemorrhagic events. Keeping the native aortic valve also leaves many options open for reintervention decades down the line should the younger patient require it. In older patients, especially when the native leaflets exhibit normal morphology, avoiding bioprosthetic valve replacement may defer complications associated with structural valve degeneration [4].

Studies have supported the choice of supracoronary interposition grafting in ATAAD in patients without a definitive indication for aortic valve replacement. The present study goes further: even with severe AR at the time of emergency surgery, valve resuspension can yield good long-term results and severe AR should not be a considered a contraindication for AAG. Few studies have examined the performance of the native aortic valve following type A aortic dissection and in these there is a lack of consensus regarding the significance of aortic regurgitation at presentation. Molteni *et al.* and Tang *et al.* found that aortic regurgitation at presentation was not a predictor of subsequent reintervention of the aortic valve or aortic regurgitation in a retrospective case series [14][15]. In contrast Pesotto*et al.* did find that moderate or severe aortic regurgitation at presentation was associated with an increased risk of moderate or severe aortic regurgitation during follow-up in patients undergoing aortic valve resuspension [16].

The long-term durability of the native aortic valve and root was found to be good in this case series. In total six patients in this series required reintervention on the native aortic root or valve. A modest deterioration in the function of the native aortic valve was observed with 9 and 3 patients developing moderate and severe aortic regurgitation respectively following discharge.

Limitations

Despite the strength of its findings, this study also has some limitations to consider. It reflects the experience of only two centres treating ATAAD and therefore only a limited number of surgeons. Despite the moderate sample size, the key conclusions relating to death and recurrence are based on outcomes with a small event rate, thus limiting the certainty of conclusions on performance of the native aortic valve after resuspension. Additionally, as with all studies reporting long-term outcomes, some patients were lost to follow-up (20%), most frequently due to patient care being continued away from the tertiary centres, which reflects the reality of patient management for such a complex disease. Furthermore, follow up of aortic root dimensions in the AAG cohort was based entirely on echocardiographic analysis rather than the gold standard cross sectional imaging. Future studies in larger groups using CT follow-up for aortic root dimensions would provide clearer conclusions on this topic.

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Tables

Ταβλε 1. ςομπαρισον οφ πατιεντ δεμογραπηιςς, βασελινε ςηαραςτεριστιςς ανδ οπερατιε ςηαραςτεριστιςς. Δισςρετε δατα ςομπαρισον ςαλςυλατιονς αρε περφορμεδ υσινγ Πεαρσον'ς χ^2 τεστ ανδ ςοντινυους δατα υσινγ τωο ταιλεδ τ-τεστ. ἅλυες πρεσεντεδ ας N(%) ορ μεαν ± στανδαρδ δειατιον.

Covariate	**AAG cohort N=63**	**ARR cohort N=53**	**P value**
Age, years	61.1 ± 15.3	58.7 ± 15.6	0.415
Gender, male	40 (63.5)	37 (69.8)	0.473
BMI	27.4 ± 4.8	29.7 ± 7.5	0.104
Hypertension	41 (65.1)	34 (64.2)	0.917
Diabetes	1 (1.6)	7 (13.2)	0.014
Chronic kidney disease	1 (1.6)	3 (5.7)	0.231
Dyslipidaemia	22 (34.9)	20 (37.7)	0.753

CVA or TIA	3 (4.8)	6 (11.3)	0.188
Ex-smoker	24 (38.1)	16 (30.2)	0.372
Current Smoker	9 (14.3)	14 (26.4)	0.019
Connective tissue disease	2 (3.2)	4 (7.5)	0.289
Euroscore II	23.4 ± 14.2	21.9 ± 13.9	0.626
Previous cardiac surgery (%)	2 (3.2)	2 (3.8)	0.860
CPB time, minutes	160 ± 62	211 ± 128	0.011
Cross clamp time, minutes	101 ± 40	203 ± 23	<0.001
Circulatory arrest, minutes	25 ± 29	19 ± 23	0.256
Moderate/severe AR on TOE (%)	19 (30.2)	21 (39.6)	0.285

Ταβλε 2 ςομπαρισον οφ μορταλιτψ, ρατες οφ ρειντερεντιον ανδ ποστ-οπερατιε ςομπλιςατιονς βετωεεν ΑΑΓ ανδ ΑΡΡ ςοηορτς. Δισςρετε δατα ςομπαρισον ςαλςυλατιονς αρε περφορμεδ υσινγ Πεαρσον'ς χ^2 τεστ ανδ ςοντινυους δατα υσινγ τωο ταιλεδ τ-τεστ. ἅλυες πρεσεντεδ ας Ν(%) ορ μεαν ± στανδαρδ δειατιον.

	AAG N=63	**ARR cohort N=53**	**P value**
30-day mortality	1 (1.6)	9 (17.0)	0.003
Return to theatre	9 (14.3)	10 (18.9)	0.506
Cerebrovascular accident	11 (17.4)	4 (7.5)	0.113
Renal failure	11 (17.4)	13 (24.5)	0.349
Deep sternal wound infection	2 (3.2)	0 (0)	0.191
Gastrointestinal bleeding	2 (3.2)	1 (1.9)	0.663
Gastrointestinal ischaemia	1 (1.6)	0 (0)	0.357
Arrthymia	23 (36.5)	13 (24.5)	0.165
Permanent pacemaker	2 (3.2)	3 (5.7)	0.511
Length of hospital stay, days	17 (10 – 29)	18 (9 – 32)	0.776

Table 3: Multivariate logistic regression using operative, 30-day, mortality as the end-point. Statistically significant results highlighted in bold (p<0.05).

Covariate	**Odds ratio**	**Standard error**	**95% confidence interval**	**P value**
Age	1.07	0.04	0.99 – 1.16	0.070
Euroscore	1.05	0.03	0.99 – 1.11	0.107
Gender (female)	1.96	1.91	0.29 – 13.3	0.492
Mod/severe AR	0.87	0.79	0.15 – 5.16	0.877
Root replacement	35.2	48.5	2.38 – 522.0	**0.010**
Circ. arrest time	1.04	0.02	1.01 – 1.08	**0.012**

Table 4: generalised linear regression model (inverse gaussian) assessing the association between patient covariates and length of hospital stay.

Covariate	Coef	Standard error	95% confidence interval	P value
Age	-0.03	0.26	-0.54 – 0.49	0.921
Euroscore	0.20	0.24	-0.26 – 0.66	0.400
Diabetes	14.4	12.1	-9.31 – 38.2	0.233
CKD	-1.20	8.11	-17.1 – 14.7	0.882
Root replacement	2.32	2.82	-3.20 – 7.84	0.410
CPB time	0.031	0.019	-0.006 – 0.07	0.102

Table 5: Cox-regression model assessing the relationship between patient covariates and long-term survival. Statistically significant results highlighted in bold (p<0.05).

Covariate	Hazard ratio	Standard error	95% confidence interval	P value
Age	1.02	0.13	1.01 – 1.05	**0.050**
Euroscore	1.02	0.02	0.99 – 1.06	0.154
Diabetes	1.58	0.89	0.53 – 4.74	0.415
Gender (female)	1.59	0.56	0.80 – 3.17	0.185
CKD	1.64	0.65	0.75 – 3.57	0.217
Root replacement	2.54	0.92	1.25 – 5.15	**0.010**
CPB time	1.00	0.01	0.99 – 1.04	0.886

Table 6: average growth rates of the annulus, sinus of Valsalva, sinotubular junction and ascending aorta in patients under-going valve resuspension following ATAAD.

Parameter	**Average Growth rate (mm/yr)**
Annulus	-0.10
Sinus of Valsalva	0.26
Sinotubular Junction	0.37
Ascending Aorta	0.34

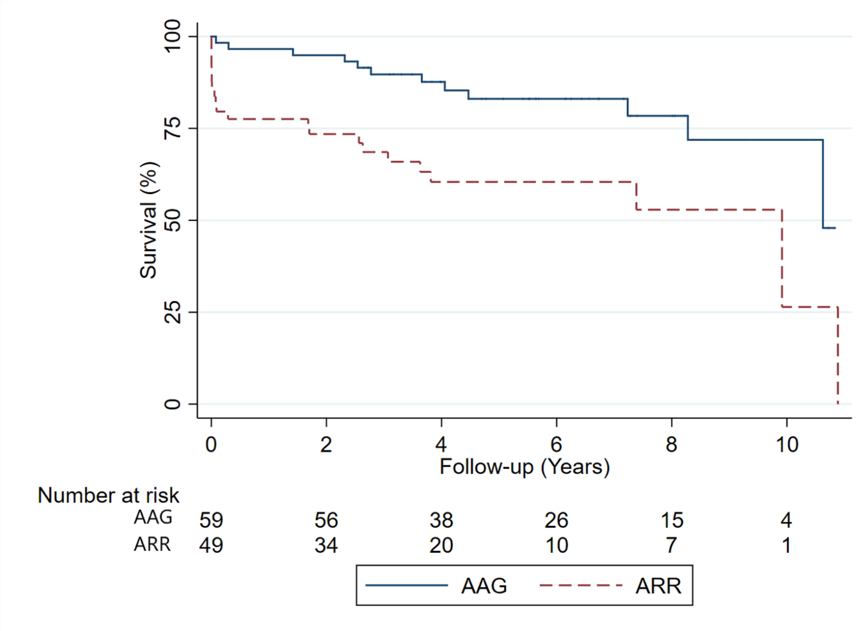

Figure 1. Kaplan Meier survival curves for AAG and ARR cohorts.

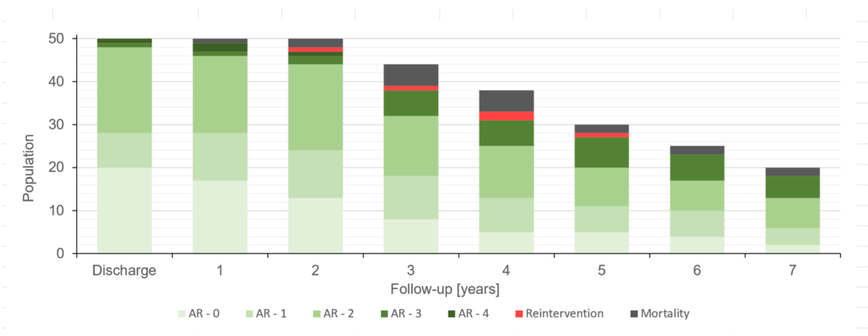

Figure 2. Degree of aortic regurgitation, incidence of reintervention and mortality in patients undergoing ascending aorta interposition graft (AAG) for ATAAD.

Appendix 1

Multivariate logistic regression using moderate/severe aortic regurgitation, reintervention on the aortic root or valve and mortality as a composite end-point.

	coeff b	*s.e.*	*Wald*	*p-value*	*exp(b)*	*lower*	*upp*
Intercept	0.722227	15.30513	0.002227	0.962363	2.059013		
Age	0.037464	0.03856	0.943969	0.331259	1.038175	0.962605	1.11
Height	-0.03079	0.030515	1.018332	0.312915	0.969676	0.913381	1.02
Weight	-0.06087	0.032887	3.426235	0.064168	0.940942	0.882204	1.00
HTN	-0.1566	1.217627	0.01654	0.897667	0.855048	0.078622	9.29
Dyslipidaemia	1.014271	1.125577	0.812003	0.367529	2.757352	0.303668	25.0
Smoker	0.09218	0.722486	0.016278	0.898476	1.096562	0.266104	4.51
Connective tissue disease	20.46982	27229.6	5.65E-07	0.9994	7.76E+08	0	#N

Euroscore	0.045374	0.047758	0.902657	0.34207	1.046419	0.952915	1.14
Cross Clamp Time	0.033291	0.023061	2.08414	0.148836	1.033852	0.988164	1.08
CPB Time	-0.02529	0.016479	2.356058	0.124797	0.975023	0.944036	1.00
Circulatory Arrest Time	0.00999	0.022154	0.203328	0.652048	1.01004	0.967121	1.05
Return to theatre	0.888856	1.377285	0.4165	0.518689	2.432345	0.16356	36.1
Aortic Regurg	1.175274	0.899779	1.706109	0.191491	3.239031	0.555293	18.8
Moderate or severe aortic regurg at presentation	-0.22752	1.465615	0.0241	0.876632	0.796505	0.045046	14.0
Number of cusps	-2.52553	4.55397	0.307557	0.579183	0.080016	1.06E-05	601
EF (%)	0.169597	0.081127	4.370233	0.036572	1.184827	1.010647	1.38