Long-term experience with valve-sparing reimplantation technique for the treatment of aortic aneurysm and aortic regurgitation

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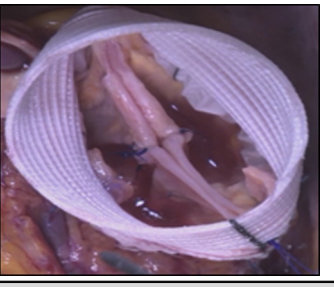
ABSTRACT

Objective: To analyze our long-term experience with valve-sparing reimplantation technique for the treatment of isolated root aneurysm, aneurysm with significant aortic regurgitation, and for isolated aortic regurgitation.

Methods: Between 1999 and 2017, 440 consecutive patients underwent valve-sparing reimplantation in our institution. The mean age of this cohort was 49 ± 15 years. Time-to-event analysis was performed with the Kaplan-Meier method, whereas significant predictors of late outcomes were explored with Cox proportional hazard model.

Results: In-hospital mortality was 0.7% (n = 3). Four hundred fourteen patients were available for long-term analysis. Median duration of follow-up was 5 years (interquartile range, 2-8.5 years). Thirty-six patients (8.5%) died during follow-up; therefore, survival was 79.7% ± 3.8% at 10 years. During follow-up we observed a linearized rate of 0.37%, 0.73%, and 0.2% patient-year, respectively, for major bleeding, thromboembolic events, and infective endocarditis. Nineteen patients required late aortic valve reoperation and freedom from valve reoperation was 89.6% ± 2.9% at 10 years and was not significantly different between groups or between tricuspid or bicuspid valve phenotypes.

Conclusions: Our study shows that valve-sparing reimplantation is associated with low perioperative mortality, a remarkably low rate of valve-related complications, and excellent long-term durability. Further, it can be safely performed also in patients with isolated aortic regurgitation and the durability of valve repair is similar regardless of the indication for surgery of valve phenotype. (J Thorac Cardiovasc Surg 2019;158:14-23)



A bicuspid AV reimplanted into a Valsalva graft and central plication of both cusps.

Central Message

Aortic valve sparing with the reimplantation technique is associated with excellent long-term results that are similar regardless of the indication for surgery or valve phenotype.

Perspective

Aortic valve-sparing root replacement with the reimplantation technique is questioned in cases of severe AR with or without root dilatation. Nonetheless valve reimplantation provides fixing of the functional aortic annulus at both the VAJ and STJ. This analysis shows that VSR can be safely performed also in patients with severe AR with or without root dilatation and provide excellent results.

See Commentaries on pages 24 and 25.

Valve-sparing aortic root replacement with the reimplantation technique (VSR) has emerged as an attractive alternative to valve replacement in patients with aortic root aneurysm.[1,2] VSR can reduce the risk of prosthesis-

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Abbreviations and Acronyms

AR = aortic regurgitation
AV = aortic valve
BAV = bicuspid aortic valve
LVEDD = left ventricle end diastolic volume
NYHA = New York Heart Association
STJ = sinotubular junction
TAAD = type A acute aortic dissection
VAJ = ventriculoaortic junction
VSR = valve sparing root replacement with the reimplantation technique

related complications, including thromboembolism, endocarditis, and anticoagulation-related hemorrhage.[3-5] Further, repaired native valve supposedly has a better hemodynamic profile and potentially better survival than any valve prosthesis.[6] However, the durability of the aortic valve (AV) is questioned in the presence of severe or eccentric aortic regurgitation (AR) that is usually associated with cusp disease. Further, because of its technical complexity, VSR is not usually considered for the treatment of AR without root dilatation.

The aim of this study was to analyze our long-term experience with VSR for the treatment of root dilatation without significant AR (ie, the conventional indication), root dilatation with severe AR (ie, debated indication), and also for the treatment of isolated AR (ie, nonconventional indication).

MATERIALS AND METHODS

This observational cohort study with unidentified patient data was approved by the review ethics board of our hospital and a waiver of consent was obtained. All adult patients who underwent VSR between 1998 and January 2017 at our institution were included in this analysis. The VSR operation was considered for all patients presenting with aortic root aneurysm or severe AR at our institution during the study period.

Clinical follow-up data were collected by telephone contact with the patient or the referring physician. Subsequent hospitalization and routine visit data were collected from hospital records and cardiologist reports.

Morbidity and mortality were reported according to the 2008 Society of Thoracic Surgeons/American Association for Thoracic Surgery/European Association for Cardio-Thoracic Surgery guidelines.[7] Early mortality was defined as any death occurring during hospital stay or during the first 60 days after the operation; any other death was considered a late death. Clinical outcomes of interest included the incidence of systemic embolism, major bleeding events, endocarditis, and reoperation on the AV for any cause.

Surgical Technique

VSR has been previously described in detail.[8] Briefly, after aortic cross-clamp and cardioplegic arrest of the heart, a horizontal aortotomy 1 cm above the sinotubular junction (STJ) is performed and the valve is carefully examined. External root dissection and preparation is followed by excision of the Valsalva sinuses. The proximal suture line is therefore carried out with 10 to 12 pledget stitches at the level of the ventriculoaortic junction (VAJ). The size of the vascular graft is then chosen by means of the height of the commissure at the level of the noncoronary/left-coronary commissure as previously described.[9] After completion of the proximal suture line, the valve is reimplanted within the graft starting from the 3 commissures. The valve is then reexamined and residual prolapse or any other lesion is addressed and corrected. The techniques of cusp repair have been previously described[10] and consist mainly of free margin plication and free margin resuspension. The special considerations in case of bicuspid valve (BAV) have been reported elsewhere.[11] Briefly, in type 0 BAV, the symmetry of cusps and sinuses was respected during valve reimplantation. In type 1 BAV with a restrictive raphe and a deficit of cusp tissue on the conjoined cusp, the valve was made symmetric by compressing the VAJ relatively more on the side of the conjoined cusp and by reimplanting the commissures with an orientation of 180°.

Echocardiographic Follow-up

Serial standardized echocardiogram examinations have been performed in our institution. At follow-up transthoracic echocardiogram, AR was graded as 0 for no regurgitation, 1+ for a regurgitant volume <30 mL, 2+ for a regurgitant volume of 30 to 44 mL, 3+ for a regurgitant volume of 45 to 60 mL, and 4+ for a regurgitant volume >60 mL.

Statistical Analysis

Continuous variables were reported as the mean ± standard deviation for variables with a normal distribution or as median and interquartile range (IQR) for non-normal distributions. Categorical variables were reported as proportions. Between-group comparison was made with analysis of variance and post-hoc Bonferroni correction for continuous variables and with the χ^2 or the Fisher exact test as appropriate for categorical variables. The follow-up time was calculated from the date of operation until either the date of death or the date of the last verified contact with the living patient. Similarly, the time to reoperation was calculated from the date of the VSR until the date of the reoperation if present or the date of the last verified contact with the patient. The time for other valve-related events was calculated until the last valid assessment of these complications. For the purpose of the study, the follow-up period was closed in June 2017 to have at least 6 months of potential follow-up for the final patients who underwent operation during 2017. Completeness of follow-up was calculated according to Clark and colleagues.[12] Length of follow-up was calculated with the reverse Kaplan-Meier method.[13] Seventeen patients (3.9%) were lost to follow-up following discharge from hospital. The median duration of follow-up for the full cohort was 5 years (IQR, 2-8.5 years) with a total cumulative follow-up of 2179 patient-years. The completeness of follow-up was 78%.

Time to event analysis was performed with the product-limit method (Kaplan-Meier). Survival curves were compared with the Tarone-Ware test. A proportional hazard model (Cox regression) was used to identify significant predictors of late survival. Predictors of late AV reoperation were analyzed accounting for the competing risk of death with competing-risk regression model with the Fine-Gray method.[14] The proportionality assumption was checked through the interaction of the candidate predictor with time. For the hazard of reoperation over time, the following covariates were considered: age, gender, body mass index, valve morphology, degree of aortic insufficiency, indication for surgery (ie, group), preoperative diameter of the VAJ, left ventricle end diastolic volume (LVEDD), preoperative New York Heart Association (NYHA) functional class, previous cardiac surgery, presence of connective tissue disorder, size of graft, concomitant procedures, concomitant cusp repair, and use of patch.

For the hazard of late death, the following covariates were considered: age, gender, body mass index, valve morphology, preoperative NYHA functional class, preoperative left ventricle ejection fraction (as 4 categories: >50%, 31%-50%, 21%-30%, and <21%), LVEDD, preexisting comorbidities (eg, chronic renal failure, pulmonary hypertension, chronic obstructive pulmonary disease, peripheral arteries disease, or diabetes), indication for surgery (ie, group), previous cardiac surgery, presence of connective tissue disorder, type A acute aortic dissection (TAAD), concomitant procedures, AV reoperation and cardiac reoperation. Reoperation on the AV was considered as a time-varying covariate. Univariable

TABLE 1. Clinical characteristics of patients according to the Indication for surgery

Characteristic	Aneurysm (n = 139 group 1)	Aneurysm + AR (n = 212 group 2)	Isolated AR (n = 76 group 3)	*P* value
Mean age (y)	47 ± 14	51 ± 15	42 ± 13	.05
Men	128 (92.1)	191 (90.1)	70 (92.1)	.7
Bicuspid AV	49 (35.2)	76 (55.9)	52 (68.4)	<.001
Grade of aortic regurgitation				<.001
0-1		0	0	
2		70 (33.0)	6 (7.9)	
3		103 (48.6)	58 (76.3)	
4	139 (100)	39 (18.4)	12 (15.8)	
NYHA functional class				<.001
I	112 (80.6)	105 (49.5)	41 (53.9)	
II	23 (16.5)	79 (37.3)	30 (39.5)	
III	3 (2.2)	28 (13.2)	5 (6.6)	
IV	1 (0.7)	0	0	
LV ejection fraction				.03
≥50%	132 (95)	175 (82.5)	69 (90.8)	
31%-49%	7 (5)	33 (15.6)	7 (9.2)	
≤30%	0	4 (1.9)	0	
LVEDD (mm)	53 ± 5	61 ± 8	63 ± 7	.02
VAJ (mm)	27 ± 3*	28 ± 4	29 ± 4*	.007*
Previous cardiac surgery	3 (2.1)	4 (1.9)	5 (6.6)	.09
Connective tissue disorder	19 (13.7)	14 (6.6)	1 (1.3)	.004

Values are presented as mean ± standard deviation or n (%). *AR*, Aortic regurgitation; *AV*, aortic valve; *NYHA*, New York Heart Association; *LV*, left ventricle; *LVEDD*, left ventricle end diastolic volume; *VAJ*, ventriculoaortic junction. *VAJ was significantly different only for group 1 versus group 3.

analysis was performed to identify clinical variables potentially associated with the outcome; variables that resulted significantly ($P < .05$) at this point were included altogether into a multivariable model to assess their independent effect.

The longitudinal evaluation of echocardiographic data (degree of AR over time) was performed using multivariate mixed-effects ordered logistic regression allowing for random patient intercept and slope. For this analysis we considered only patients who were alive and we did not adjust for the competing risk of death but for the degree of AR at discharge from hospital; further, patients were nested into the 3 groups of interest.

All analyses were conducted with Stata IC version 15.1 (StataCorp LP, College Station, Tex).

RESULTS

Between 1999 and 2017, a total of 923 adult patients were treated for AV repair at our institution. Of them, 440 consecutive patients (47.7%) underwent VSR and are the subject of this study. For the purpose of this study patients were dived into 3 groups according to the indication for surgery: aortic root aneurysm without AR in 139 patients (31.6%) (group 1), aneurysm with significant AR in 212 (48.2%) (group 2), and isolated AR in 76 patients (17.3%) (group 3). Further, 13 patients (2.9%) presented with TAAD and make a standalone subgroup.

Patients' characteristics and perioperative data are presented in Tables 1 and 2. Mean age for the full cohort was 49 ± 15 years and 91% of patients were men. A connective tissue disorder (mainly Marfan syndrome) was present in 34 patients who usually presented with isolated aortic aneurysm (group 1). These patients were also significantly younger than the others (35 ± 15 years vs 50 ± 14 years; $P < .0001$).

Early Outcomes

The proportion of associated procedures, mainly mitral valve repair, and duration of cardiopulmonary bypass were comparable among groups. Some type of cusp repair was added in more than half of patients in each group and in almost 100% of patients with isolated AR. A pericardial patch was used in a minority of patients and almost never in patients without significant AR. Three patients (0.6%) died early after surgery (2 with preoperative TAAD) and 1 patient (0.2%) required early (during the same hospitalization) reoperation on the AV (underwent re-repair). Median follow-up in group 3 (3.5 years; IQR, 1.7-5.8 years) was shorter than in the other 2 groups (group 1: 4.7 years [IQR, 2-8.5 years] and group 2: 5.5 years [IQR, 2.2-9.7 years) revealing that VSR for isolated AV repair was introduced in our practice in more recent years.

Late Reoperations

Nineteen patients (4.6%) required late AV reoperation for a linearized rate of re-intervention of 0.8% patient-year. Median interval of reoperation was 5.2 years (IQR, 2.8-9.6 years). No patient died at reintervention. Indications

TABLE 2. Perioperative outcomes of patients according to the indication for surgery

Outcome	Aneurysm (n = 139 group 1)	Aneurysm + AR (n = 212 group 2)	Isolated AR (n = 76 group 3)	*P* value
Graft size (mm)	30	30	30	.3
Cardiopulmonary bypass time (min)	145 ± 35	150 ± 34	151 ± 26	.6
Concomitant procedures	37 (26.6)	54 (25.5)	13 (17.1)	.2
Mitral valve repair	5 (5.0)	13 (6.1)	6 (7.9)	
Hemiarch	4 (2.9)	12 (5.6)	0	
Coronary artery bypass graft	18 (0.7)	9 (4.2)	4 (5.2)	
Cusp repair	76 (54.7)	170 (80.2)	74 (97.4)	<.001
Patch	1 (0.7)	15 (7.1)	4 (5.2)	.02
Re-exploration for bleeding	21 (15.1)	23 (10.9)	8 (10.5)	.4
Permanent pacemaker insertion	9 (6.5)	7 (3.3)	5 (6.6)	.3
30-d death	1 (0.7)	0	0	.3

Values are presented as median, mean ± standard deviation, or n (%). *AR*, Aortic regurgitation

for reoperations were recurrent severe AR (n = 9: 6 underwent AV re-repair and 3 underwent replacement), severe aortic stenosis (n = 3: all 3 underwent AV replacement), AV endocarditis (n = 4: all 4 underwent AV replacement), and severe mixed AR and stenosis (n = 3: all 3 underwent AV replacement). Freedom from reoperation on the AV was 100% at 1 year, 96.5% (95% confidence interval [CI], 93.4%-98.2%) at 5 years, and 89.6% (95% CI, 82.7%-94%) at 10 years. Freedom from reoperation was not different among groups ($P = .09$) and between tricuspid AV and BAV ($P = .1$) (Figure 1, *A* and *B*). At univariable regression analysis, only age at surgery (subdistribution hazard ratio [SHR], 0.96; 95% CI, 0.93-0.99; $P = .008$), preoperative LVEDD (SHR, 1.05; 95% CI, 1.00-1.1; $P = .04$) and connective tissue disorder (SHR, 3.5; 95% CI, 1.1-10.8; $P = .03$) were significant predictors of late reoperation. Due to the limited number of events, a multivariable analysis was not performed.

Three more patients underwent reoperation for mitral valve repair: 1 for coronary artery bypass grafting, 1 heart transplantation for end-stage heart failure, and 2 balloon dilatations of the pulmonary homograft (patients with previous Ross operation before VSR). Freedom from all cardiac reoperation was therefore 93.5% ± 2% at 10 years.

Other Valve-Related Complications

No patient presented valve thrombosis, but systemic embolism and major bleeding events occurred in 8 patients (1.9%) and 10 patients (2.3%) during follow-up for a linearized rate of 0.3% and 0.4% patient-year, respectively. Five patients (0.4%) presented infective endocarditis of the AV for a linearized rate of 0.2% patient-year.

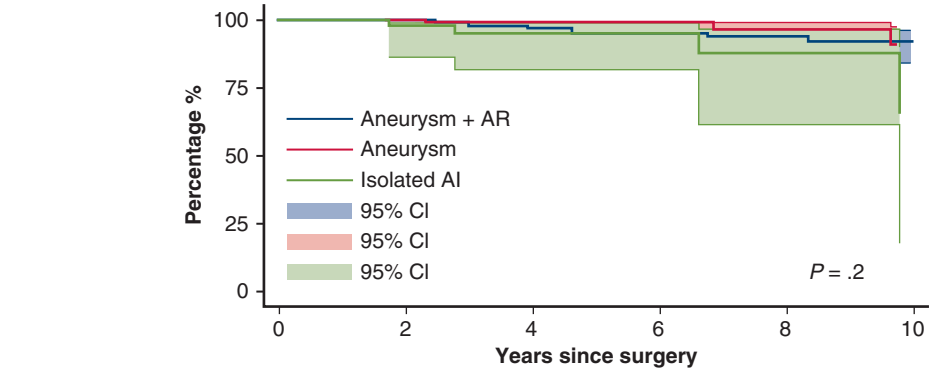
Long-Term Survival

During follow-up there were 36 late deaths (8.7%) for a linearized mortality rate of 1.6% patient-year. Ten deaths were cardiac-related (4 sudden or unexplained, 3 chronic heart failure, 2 cerebral hemorrhage, and 1 following reoperation for myocardial revascularization); 26 deaths were from noncardiac causes: 10 cancer, 6 sepsis (not infective endocarditis), 2 acute type-B aortic dissection, 1 ruptured abdominal aortic aneurysm, 3 trauma, 2 chronic renal failure, 1 bowel ischemia, and 1 Parkinson disease. Overall survival is depicted in Figure 2, *A*, and was 95.2% (95% CI, 91.9%-97.2%) and 79.8% (95% CI, 71.1%-86.0%) at 5 and 10 years, respectively. Survival was also not different by group (Figure 2, *B*) after adjusting for age, preoperative NYHA functional class, left ventricle ejection fraction, and presence of connective tissue disorder ($P = .3$) in a multivariable Cox regression analysis (hazard ratio [HR], group 2 vs group 1, 1.2 [$P = .7$] and HR group 3 vs group 1, 0.5 [$P = .5$]). Further, freedom from valve-related deaths was 97.3% (95% CI, 93.2%-98.8%) at 10 years.

Univariable Cox-regression analysis identified age (HR, 1.06; $P < .001$), male gender (HR, 0.35; $P = .01$), presence of BAV (HR, 0.19; $P = .002$), preoperative NYHA functional class (HR, 1.7 for every class increase; $P = .02$), peripheral artery disease (HR, 5.04; $P = .03$), and TAAD (HR, 7.04; $P = .001$) as significant predictors of late death. Reoperation on the aortic valve was not associated with late survival ($P = .2$). In a multivariable model only age, male gender, and TADD were significantly associated with death. Figure 3 shows AV reoperation-free survival and the competing risk of reoperation and death. At 10 years, reoperation-free survival is 71.5% (95% CI, 62.3%-78.8%).

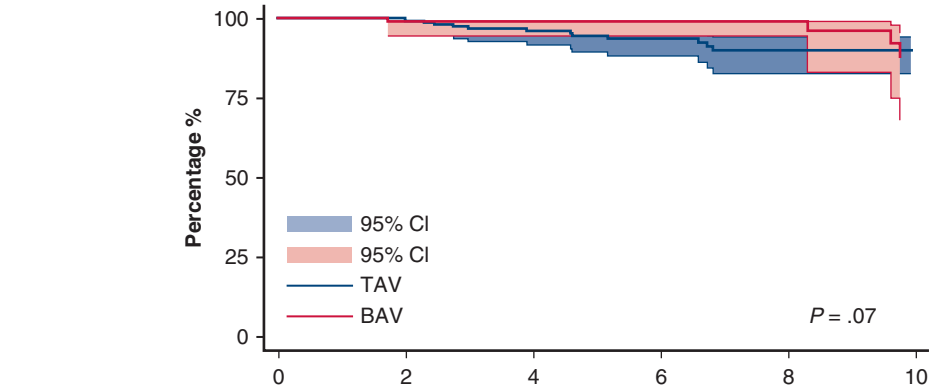
Echocardiographic Studies

Every patient underwent a transthoracic echocardiogram before discharge from hospital. At discharge, 227 patients (51.6%) had no AR, 205 (46.6%) had mild AR (ie, grade 1+) and 5 (1.1%) had mild to moderate AR (ie, grade 2+). During follow-up, 399 patients (96.4%) out of 414



Number at risk						
Group = Aneurysm + AR	204	154	119	85	55	33
Group = Aneurysm	135	98	72	45	32	16
Group = isolated AI	67	46	30	14	8	3

A



Number at risk						
Valve = TAV	253	178	134	87	57	32
Valve = BAV	164	126	91	57	38	20

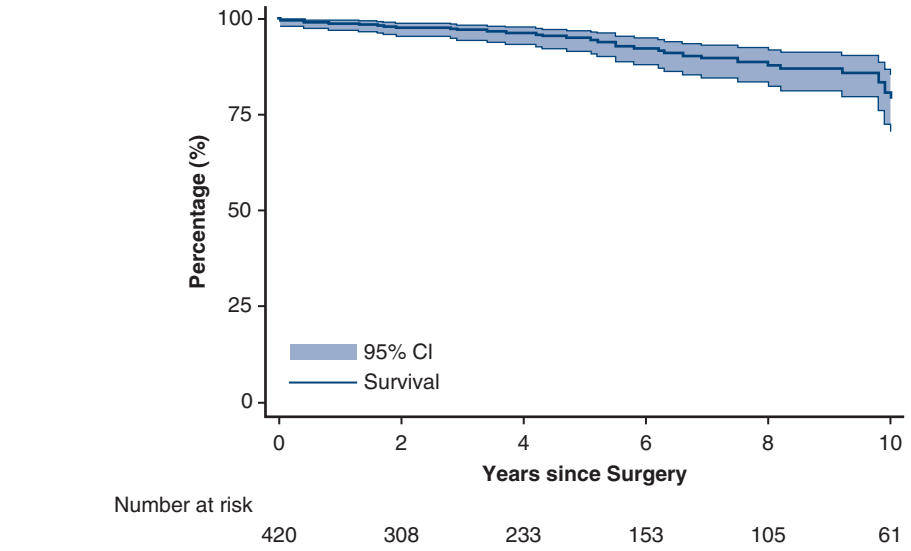
B

FIGURE 1. A, Freedom from reoperation on the aortic valve by groups. At 10 years: 91% ± 5.8% for group 1, 92.2% ± 2.9% for group 2, and 65.9% ± 19.8% for group 3 ($P = .2$). B, Freedom from reoperation by valve morphology. At 10 years: 90.2% ± 2.9% for tricuspid aortic valve (TAV) and 88% ± 6.3% for bicuspid aortic valve (BAV) ($P = .07$). *AR*, Aortic regurgitation; *AI*, aortic insufficiency; *CI*, confidence interval.

had transthoracic echocardiogram for total of 2391 examinations. Each patient received a median of 5 scans (IQR, 2-7 scans) for a cumulative echocardiogram follow-up of 2122 patient-years. The 379 patients who did not require reoperation on the aortic valve had a last echocardiogram at a median follow-up of 4 years (IQR, 2-7 years) since surgery. A total of 2276 echocardiogram measurements of AR in 408 patients were available. Figure 4 shows the probability of developing AR over time considering patients who were alive. The percentage of patients in each grade of AR has changed significantly over time ($P < .001$). The percentage of patients with AR grade 0 decreases from 54% at 1 year to 34% at 10 years after the procedure, whereas the percentage of patients with grade 1 and 2 increased progressively from 40% to 51% and from 5% to 11%, respectively. The percentage of patients with grade 3 or 4 AR increased from 0% at discharge from hospital to 2% and 1%, respectively, at 10 years.

DISCUSSION

Preservation of the native valve with valve-sparing procedures potentially offers a reduction in the risk of prosthesis-related complications, particularly the anticoagulation-related complications with a mechanical prosthesis; the risk of valve degeneration and reoperation with a bioprostheses, particularly in young patients[15]; and a better hemodynamic profile compared with any valve prosthesis. In the present study, we reviewed our 20 years' experience with the valve-sparing reimplantation technique in patients presenting with aortic root aneurysm, aneurysm with significant regurgitation, or isolated severe AR. Our analysis shows that VSR can be safely performed also in



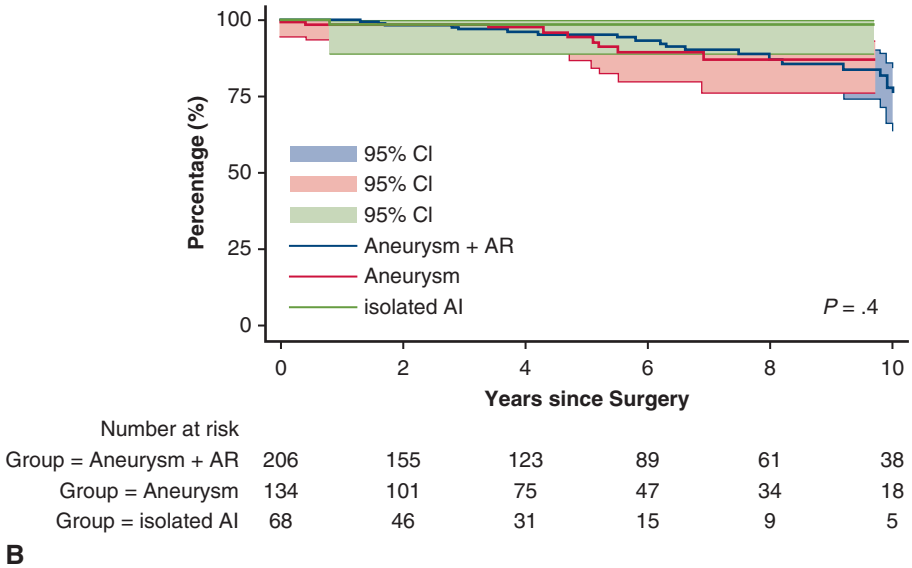


FIGURE 2. A, Long-term survival for the full cohort. At 10 years: 79.8% ± 3.8%. B, Long-term survival by groups. At 10 years: 87.9% ± 4.2% for group 1, 75.8% ± 5.3% for group 2, and 98.4% ± 1.6% for group 3 ($P = .3$). *CI*, Confidence interval; *AR*, aortic regurgitation; *AI*, aortic insufficiency.

patients with isolated AR and provide excellent results in terms of valve durability, valve-related complications, and long-term survival (Video 1). Our analysis further confirms the low rates of valve-related complications such as thromboembolism, bleeding, and infective endocarditis reported in a previous meta-analysis.[16]

The concern for the durability over time of the spared/repaired AV has slowed the diffusion of this technique in favor of the conventional Bentall operation. Our study shows an excellent durability of the AV with a freedom from reoperation of around 90% at 10 years also in patients who presented with severe AR at surgery.

Recently, David and colleagues[17] presented long-term results with VSR and reported a freedom from reoperation of more than 95% at 10 years. Several differences between the 2 series may explain this disparity. In our cohort we had a higher prevalence of BAV (40.2% vs 13.5%) and a subgroup of patients (group 3, accounting for 17.3% of the cohort) presented with isolated AR. Therefore, cusp repair was needed in up to 72.7% of our patients, in almost all patients with BAV (97%), and a pericardial patch was used in 4.5% of patients (two-thirds of whom had a BAV). David and colleagues[17] reported a conservative approach and employs VSR only when the cusps are normal or have minimal abnormalities, and indeed they reported a cusp repair in 64% of patients and no patch use. We believe that VSR can be coupled with cusp repair in a certain proportion of patients who present with AR with severe cusp lesions and still

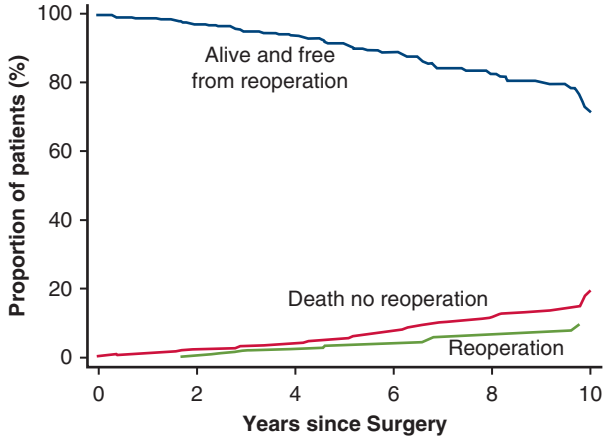


FIGURE 3. Aortic valve reoperation-free survival and the competing risks (cumulative incidence function) for reoperation on the aortic valve and death (without reoperation) at each moment in time in the overall cohort.

provide good long-term results and a significant benefit compared with valve replacement. In these patients, at the expense of only a slightly increased risk of reoperation over time, we can spare them a prosthetic valve (most likely a mechanical valve considering the young age of the current cohort) and notably the prosthesis-related complications. Indeed, the rates of prosthesis-related complications in our series are notably lower than those from large recent registries[18,19] in patients of similar age treated with valve replacement or Bentall procedure.[20] It is nevertheless a matter of experience whether a valve with significant cusp lesion can be repaired with acceptable probability of long-term durability or if it should be replaced. Further, although some degree of AR develops over time, the risk of moderate or severe AR (ie, grade 3 and 4) is very low at 10 years and similar to David and colleagues.[17]

It also noteworthy that in more than 50% of patients without significant AR before surgery underwent cusp repair. Reimplantation of the valve within a graft that is

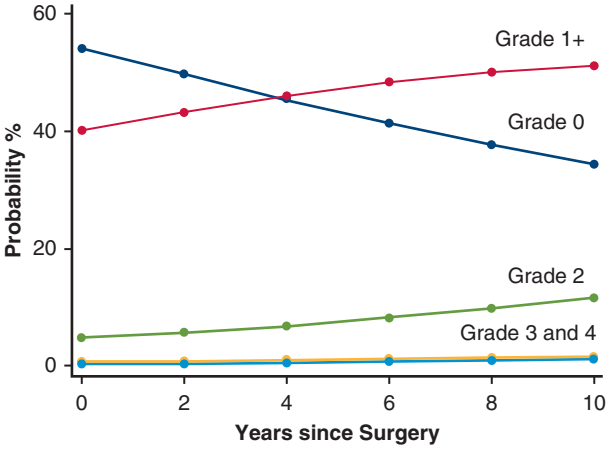


FIGURE 4. Temporal trend of aortic regurgitation after the operation. *Grade 0*, blue; *grade 1*, red; *grade 2*, green; *grade 3*, yellow; *grade 4*, cyan.

necessarily smaller than the native dilated aorta is invariably associated with increased cusp mobility afterward that may therefore result in cusp prolapse and regurgitation. Therefore, it is of paramount importance to reassess the cusps after reimplantation and to correct any residual prolapse or defect to improve the durability of repair.

A growing number of patients with isolated AR and large VAJ (>28 mm), that is almost invariably present with a BAV, have been treated with VSR in our institution in recent years despite a normal or only slightly dilated aortic root (diameter, 40-45 mm) that, according to current guidelines,[21,22] would not need replacement. The use of VSR in these BAV patients was not primarily aimed to prevent late aortic events, whose risk seems to be low if the aorta size is normal at time of surgery,[23] but has the double purpose of stabilize the aortic annulus at both the level of VAJ and STJ and restore the valve symmetry. Previous studies have shown the role of VAJ on AR recurrence,[24] and we have previously shown that durability of BAV repair is improved with VSR compared with subcommissural annuloplasty.[25] Cusp repair plus external ring[26] or suture annuloplasty[27] have been proposed for these patients. Lansac and colleagues[26] reported on the influence of external ring plus cusp repair in a series of 62 patients with isolated AR. They reported a freedom from reoperation and freedom from AR grade $\geq$3 of 97.5% and 82.2%, respectively, at 7-year follow-up.[26] In our group 3 we had similar results in terms of freedom from reoperation (87%) and freedom from moderate-severe AR (84%) at 7 years. Nonetheless, important differences, particularly the prevalence of BAV (higher in our study) and use of pericardial patch (higher in the study by Lansac and colleagues[26]), make the 2 series difficult to compare. Similarly, Schneider and colleagues[27] recently reported the effect of suture annuloplasty on isolated repair of BAV. At 5 years they observed a freedom from reoperation of 92.6% and freedom from significant AR (ie, grade $\geq$ 2) of 79.5%. In our patients with BAV and isolated AR (n = 52), we recorded similar results with a freedom from reoperation of 97% and freedom from AR (ie, grade $\geq$ 2) of 78.3%. Although simpler to implement, we believe that these techniques (ie, external ring and suture annuloplasty) cannot reach the true level of the VAJ without deep root dissection, particularly at the level of the right coronary sinus; therefore, they provide only partial support on a supra-annular level and we fear that the effect may not be stable over time. We hope that longer follow-up studies will provide some answers.

It has been proposed that BAV configuration, particularly the orientation of the commissure, may have an influence on valve durability.[24] Therefore, our current practice with type-1 BAV is to restore the valve symmetry with the 2 commissures at the 180° configuration. Restoring valve symmetry also increases the mobility of the conjoined cusp and allows a direct closure after resection of the raphe avoiding the use of pericardial patch that has been associated with worse

VIDEO 1. In this short video, Dr Mastrobuoni explains the relevance of the valve-sparing root replacement with the reimplantation technique and the major findings of the study. Video available at: https://www.jtcvs.org/article/S0022-5223(18)33148-9/fulltext.

outcome.[11] According to these criteria, the proportion of patients with BAV and severe AR who undergo VSR in our institution has increased through the years and currently is more than 80%. Klotz and colleagues[28] recently reported a high rate of reoperation past 10 years in BAV patients and have questioned the appropriateness of VSR in these patients. We have observed a lower cumulative incidence of reoperation at 10 years (2.2% vs 5.3%) and have too few patients at risk after this point as to do a meaningful estimation of the risk afterward. Nonetheless, it is remarkable that in the series by Klotz and colleagues[28] a high proportion of BAV patients (around 12%) required a pericardial patch. This reveals the complexity of the valves they had to deal with and may explain the late failures.

Also some patients with tricuspid AV and only mildly dilated root (40-45 mm) received a VSR in our series. Similarly, in these cases VSR was employed to stabilize a dilated VAJ or was used in cases where the aortic wall appeared particularly thin and fragile.

For many years, we have been using a Valsalva graft (Gelweave Valsalva; Vascutek Ltd, Renfrewshire, Scotland) for this operation. It is still a matter of debate whether neosinuses should be recreated during the procedure because a clinical benefit has not yet been demonstrated. Nevertheless, we believe that the use of this graft simplifies rather than complicates the procedure. Indeed, we routinely use the height of the non/left commissure for the choice of the graft size and, because the height of the STJ in the graft equals its diameter, this commissure has to be reimplanted at the level of the neo-STJ. Also, the 2 other commissures should be reimplanted at this level but the graft is tailored proximally to match any difference in height of the left/right and right/noncommissures to avoid distortion.

Finally, long-term survival is another important end point of this procedure. We observed a survival of around 80% and a stunning freedom from valve-related death of more than 95% at 10 years. Nonetheless, later survival of patients who required reintervention on the AV was not significantly different of those who did not. Survival at 10 years with VSR is therefore significantly better than with AV replacement (around 70% in large registries of patients of similar age[18,19]). We can hypothesize that VSR eventually confers a survival benefit through a significant reduction of valve-related complications. Recently, Klotz and colleagues[28] showed that long-term survival was comparable to that of the matched general population in Germany. David and colleagues[17] reported even higher survival at 10 years. A slightly older mean age and a higher prevalence of associated procedures in our cohort, mainly mitral valve and coronary surgery, may explain this difference.

Study Limitations

Our study has several limitations that should be taken into account. We started the VSR program 20 years ago, although most of our patients underwent operation in recent years; the median follow-up is indeed short; and we have <10% of the initial cohort at risk at 12 years after surgery. The nonsignificant difference in outcomes between group 3 (isolated AR) and the other 2 groups may be due to the fact that group 3 included a smaller number of patients who were also younger and with a shorter follow-up. Further, this was a single-center experience with all operations carried out by a very limited number of surgeons and the results may not be generalizable. Finally, the limited number of adverse events, particularly valve failure, precludes any robust statistical analysis for the identification of significant predictors.

CONCLUSIONS

Our long-term experience with the AV-sparing aortic root replacement with the reimplantation technique confirms the excellent results in terms of patient survival and freedom from valve-related complications, including reoperation on the valve. Our study also confirms the excellent durability of the repair in cases of BAV. This operation can also be safely performed in patients without root dilatation. A longer follow-up well into the second decade will confirm if the valve function remains stable past 10 years, particularly in patients with isolated AR.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://aats.blob.core.windows.net/media/18May01/28ABC%202.Aortic%20Endovascular/S86%20-%20Part%202/S86_1_webcast_040454597.mp4.

Conflict of Interest Statement
Authors have nothing to disclose with regard to commercial support.

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Key Words: aortic valve sparing, reimplantation

Discussion

Dr Abe DeAnda, Jr *(Galveston, Tex)*. Stefano, thank you for that nice presentation. I have 2 questions. The focus of your presentation is really group 3, the nonconventional patients who are getting valve-sparing root replacements without having aneurysmal disease. In this case I think, correctly, it is unconventional: they are younger, they had more bicuspid aortic valves than the other groups, and they required more time in repairing or cusp repair. How did you decide which of your patients undergo a valve-sparing root replacement for isolated aortic insufficiency, and, with an intent to treat, did you have some patients who you were planning for this operation who ended up getting a valve? That's my first question.

My second question: Your results are a little bit different than Tirone David's results, but I think your patient population is a little bit different, especially with this second and third group. Could you perhaps expand on that a little bit?

Dr Stefano Mastrobuoni *(Brussels, Belgium)*. Thank you. For the third group, of course, as you said, these were young patients with a bicuspid valve. In our opinion, the valve-sparing reimplantation is the best technique to fix completely the functional aortic annulus at the level of both the

ventriculoaortic junction and the sinotubular junction. With bicuspid valve, this allows us also to restore the symmetry. We think this is an important point: Restore the symmetry. This allows us to avoid the use of patch if we need to cut the raphe and reconstruct the valve because it allows us to put the conjoined cusps closer together. Definitely there are some advantages, particularly for bicuspid valve.

Then, any time a valve can be repaired, we will repair the valve and choose this operation. The only valve that cannot be repaired is the valve with severe calcification where we should use an extensive patch. So this kind of valve will be replaced. We consider this technique for all valve repairs, particularly in the case of bicuspid valve, young patient, and where we have the opportunity to completely fix the valve at every level.

Regarding your second question, yes, our results are probably a bit lower than Dr David's study published last year, but, again, the populations are a bit different. For example, Dr David's bicuspid valve patients made up only 10% of his cohort; we have almost 40% bicuspid valve patients. Also, in 5% of patients we used a patch. Dr David never used a patch. He says that his population is highly selected because he does not want to repair cusps. So the cusps have to be normal or have only minimal abnormalities. We have an entire group, the third group, of patients who presented with cusp disease, but also in the second group we had more than 50% who required cusp repair.

So probably we are more aggressive, we are more liberal, and we have been using this technique even in patients with significant cusp disease, because we think that even if the risk of reoperation is a bit higher, the results are still better than a prosthesis, that most likely would be a mechanical prosthesis, considering the young age of this cohort.

Dr DeAnda. If I can ask you just to clarify the answer to that first question, so even a bicuspid valve that you are going to repair without a dilated annulus you may still choose this operation?

Dr Mastrobuoni. No. That disease is very rare. That is not dilated annulus, bicuspid valve.

Dr Eric Roselli *(Cleveland, Ohio)*. The decision maker is the annuloaortic ectasia, correct?

Dr Mastrobuoni. Yes, of course.

Dr Roselli. What do you define as a dilated annulus then?

Dr Mastrobuoni. For the ventriculoaortic junction, more than 26.

Dr Edward P. Chen *(Atlanta, Ga)*. Great study, nice presentation. It's not surprising that in the aneurysm and aortic regurgitation group plus the isolated valve repair group there was a high percentage of cusp repair, but I was surprised that in the aneurysm with no aortic insufficiency group about 54% had cusp repair, and you would think that if there was no aortic insufficiency before that it was just a matter of recreating the root geometry. I was wondering if you could elaborate on that a little bit.

Dr Mastrobuoni. If you think about it, if you have a dilated root and there is no aortic insufficiency before surgery, when you put the valve inside a smaller graft, right, because we had a 50-mm root and then we are putting in a 30-mm graft, the cusp mobility will improve, and you may have prolapse because now there is an excess of motion of the cusp.

Dr Chen. Would you consider using a larger graft, like a 34 or a 36, for that exact reason, because you are absolutely right if you have a 5.5-cm root and you have a large cusp if there is no aortic insufficiency, and 30 seems a little bit smaller. I know you size based on the height of the left noncommissural post, but maybe consider leaflet height as another way to size, particularly in this situation.

Dr Mastrobuoni. That's right.