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REVIEW ARTICLE

Long-term experience with valve-sparing root reimplantation surgery in tricuspid aortic valve

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Abstract

Objective To analyze our long-term experience with valve-sparing reimplantation technique in treating aortic root aneurysm, aortic regurgitation, and aortic dissection in patients with tricuspid aortic valve.

Methods Between March 1998 and October 2018, 303 consecutive patients underwent valve-sparing reimplantation in our institution. The mean age of this cohort was 52.9 ± 15 years. Time to event analysis was performed with the Kaplan-Meier method. Risk of death, reoperation, and aortic regurgitation (AR) recurrence were analyzed using the cox-regression method.

Results In-hospital mortality was 1% ($n = 3$) of which two were admitted for acute aortic dissection. Median follow-up was 5.81 years ([IQR]: 2.8–10 years). Thirty-nine patients (14.4%) died during follow-up. At 5 and 10 years, overall survival was 92 ± 2%and 75 ± 4.9%, respectively. Seventeen patients required late aortic valve reoperation. Freedom from valve reoperation was 95 ± 2% and 90 ± 3%. Freedom from AR > 2+ and AR > 1+ at 10 years was 91 ± 4% and 71.5 ± 4.6%, respectively. Significant multivariate predictors of death included age, New York Heart Association dyspnea class (NYHA), type A acute dissection (TAAD), and preoperative left ventricular end-diastolic diameter (LVEDD). Significant multivariate predictors of AR recurrence included indication for surgery, previous cardiac surgery, and presence of preoperative AR. Freedom from events like major bleeding, thromboembolic events, and infective endocarditis at 10 years were 97%, 98%, and 96%, respectively.

Conclusions Aortic valve-sparing with the reimplantation technique has been performed for over two decades in our institution, and the results in patients with tricuspid aortic valve (TAV) are excellent in terms of survival and freedom from valve-related adverse outcomes including valve reoperation. These results continue supporting the use of valve sparing root replacement using the reimplantation technique (VSRR) in patients with aortic aneurysm, irrespective of whether they have preoperative AR or not. VSRR is safe, durable, and reproducible, but further follow-up, well into the second decade is still necessary.

Keywords Aortic valve repair · Aortic valve-sparing surgery · Tricuspid aortic valve

Introduction

Aortic valve-sparing root replacement techniques were first introduced into literature in 1992 by Dr. Tirone David [1, 2] and by Dr. Magdi Yacoub in 1993 [3] as an attractive alternative to combined aortic valve (AV) preservation and ascending aorta replacement in cases of aortic root aneurysm. The David operation, also called reimplantation technique, witnessed numerous technical modifications to accompany aortic anatomy and functional findings leading to the development of artificial sinuses and aortic stabilization [4–7]. Its advantages over

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the Yacoub or Remodeling technique include AV annulus stabilization and reduced risk of hemorrhage [8–10]. Despite good results in aortic root aneurysm, the durability of repair in the presence of AR remains controversial due to the presence of AV disease and, in most of those cases, the necessity to add leaflet repair to the reimplantation procedure. We have previously published our institutional results, mainly in Marfan Syndrome [11] as well as in bicuspid aortic valve (BAV) [12]. This study is a focus on our long-term experience after VSRR in TAV for the treatment of root dilatation with or without significant AR as well as for treatment of dystrophic AR with annuloectasia.

Materials and methods

Patient population

Between March 1998 and October 2018, 303 consecutive patients with TAV underwent VSRR in our institution. This observational study was approved by the Review Ethics Board of Université Catholique de Louvain, and a waiver of consent was obtained.

Indications for the valve-sparing operation included aortic root aneurysm with or without significant AR as recommended by the guidelines [13, 14] dystrophic AR with annuloectasia or acute aortic dissection.

Operative techniques

All patients were operated through full sternotomy, under cardiopulmonary bypass. After aortotomy, the valve was exposed using three commissural stay stitches pulled upward and outward.

We have described the details of the VSRR technique in case of TAV in a previous publication [15]. Briefly, root dissection is performed as low as possible, to the level of the basal ring except in the area of the membranous septum where external root dissection is limited by the roof of the right atrium (Fig. 1). The prosthesis is tied down proximally using 10 to 12 polytetrafluoroethylene-reinforced braided sutures passed along the circumference at the level of the basal ring except at the membranous septum where the suture line passes along the cranial border of the membranous septum to avoid the bundle system [16]. Since it was available on the market, the Gelweave Valsalva graft (Vascutek Ltd., a Terumo Company, Renfrewshire, Scotland) replace the straight tube graft. Sizing of the Valsalva graft is done by measuring the height of the commissure between the noncoronary and the left coronary sinuses [17]. Cusp prolapse was treated by free margin central plication or by free margin resuspension with a running suture of polytetrafluoroethylene [18]. Cusp perforation or large commissural fenestration inducing AR was repaired with pericardial patch. Assessment for cusp coaptation was always reevaluated after VSRR using visual inspection and the Schäfers caliper to measure the effective height [19]. Any residual cusp prolapse was corrected adding central plication stitch until reaching the free margin and an effective height of 8 to 10 mm and all three free margins were exactly at the same level.

Echocardiographic assessment and follow-up

Preoperative AR characteristics and aorta dimensions were obtained from intraoperative transesophageal echocardiography (TEE).

All procedures were followed by perioperative transesophageal echocardiography to assess the degree of residual AR and the orientation of its jet (if present). Prerequisites for a successful repair included a coaptation length of at least 5 mm at the midportion of the free margin and an effective height of 8 to 10 mm. Presence of residual moderate AR or mild eccentric AR was an indication for re-exploration of the aortic valve [20, 21].

Clinical follow-up data was obtained by direct phone contact either with the patient or with the referring physician. Data from hospitalization and outpatient visits was collected from hospital records and cardiologists' reports. Key endpoints included survival status, as well as incidence of systemic embolism, major bleeding events, endocarditis, and reoperation on the aortic valve for any cause.

All patients benefited from transthoracic echocardiography (TTE) upon discharge and at regular intervals during follow-up. Clinical follow-up was completed in 93% of cases with a median follow-up of 5.81 years (inter-quartile range [IQR], 2.8–10 years.). Total cumulative follow-up was at 1760 patient-years.

Early mortality was defined as any death occurring during hospital stay or during the first 30 days after the operation while any other death was considered as late mortality. Clinical outcomes of interest included the incidence of systemic embolism, major bleeding events, and reoperation on the aortic valve for any cause [22].

Statistical analysis

Categorical variables are presented as numbers and percentages. Continuous variables are presented as mean ± SD. Normal distribution of the data was tested using Kolmogorov-Smirnov test and visual analysis. Time to event analysis was performed with the Kaplan-Meier

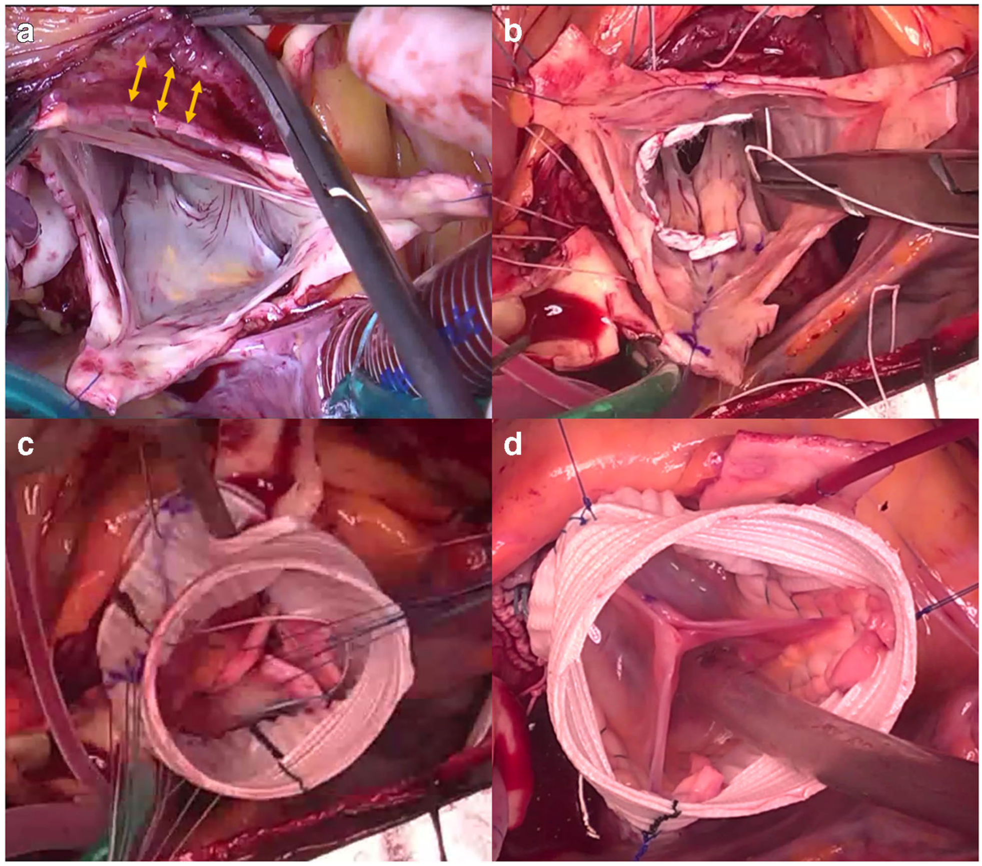

Fig. 1 Surgical steps of the valve-sparing root replacement reimplantation technique in Tricuspid AV. After external root dissection is performed according to "El Khoury Deep Root Dissection" (**a**), a proximal suture line of pledgeted sutures is passed along the basal ring (**b**), and a Gelweave Valsalva graft is descended onto the valve (**c**), before it is reimplanted with a distal suture line (**d**)

method. A $p < 0.05$ was considered statistically significant. All p values are two-sided. Statistical analyses were performed using IBM SPSS 25 (IBM Corporation, Armonk, NY).

For the hazard of death, the following covariates were considered: age, gender, height, weight, body surface area, preoperative left ventricle ejection fraction (LVEF; as three categories: > 50%, 31–50%, < 31%), preoperative AR grade, preoperative NYHA, LVEDD, preoperative maximal aorta diameter, connective tissue disorder, pre-existing comorbidities (chronic renal failure, pulmonary hypertension, chronic obstructive pulmonary disease, peripheral arteries disease, diabetes), indication for surgery (group), TAAD, cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) time, presence of leaflet repair, additional procedures, and AV reoperation. The same covariates were considered for AV reoperation and for risk of moderate to severe AR (AR ≥ 2+). The latter endpoint was considered at the first appearance of an AR greater than or equal to 2+, irrespective of reoperation, or of reduction in AR grade. Univariable analysis was performed to identify clinical variables potentially associated with the outcome; variables that resulted significantly ($p < 0.05$) at this point were included altogether into a multivariable model in order to assess their independent effect.

Results

Preoperative and perioperative data

Patients' characteristics as well as preoperative echocardiographic data are summarized in Table 1. Mean age of the patient cohort was 52.9 ± 15.3 years, ranging between 11 and 85 years, and 88.4% of them were males. Connective tissue disorder involved at least 42 (14%) of those patients, of which the majority ($n = 34$) had Marfan Syndrome. This subgroup of patients presented mainly for aneurysm either with AR (38%) or without AR (62%). They were also significantly younger than the rest of the cohort (36 ± 16 years vs. 52.9 ± 15.3 years, $p < 0.001$). Indication for surgery included aneurysm without AR (AR 0 to 1+, $n = 111$, 36.6%), aneurysm with significant AR (AR ≥ 2+, $n = 154$, 50.8%), dystrophic AR with annuloectasia ($n = 25$, 8.3%), and TAAD ($n = 13$, 4.3%). Out of the 49 patients who had a previous cardiac surgery, 31 (10.2%) had previously benefited from a Ross procedure, where dilatation of the autograft was treated with

Table 1 Patients demographics

Patients demographics	$n = 303$
Age (years), mean ± SD	52.9 ± 15.3
Male Gender, *n* (%)	268 (88.4%)
Height (cm), mean ± SD	177.4 ± 10
Weight (kg), mean ± SD	84.5 ± 18.3
BSA, mean ± SD	2.0 ± 0.2
Connective tissue disease, *n* (%)	
Marfan	34 (11.2)
Others (Loeys-Dietz, Ehler-Danlos, ACTA2)	8 (2.6)
Indication for surgery*	
Aneurysm, *n* (%)	111 (36.6)
Aneurysm + AR, *n* (%)	154 (50.8)
Dystrophic AR with annuloectasia, *n* (%)	25 (8.3)
Type A acute dissection, *n* (%)	13 (4.3)
Clinical characteristics	
NYHA functional class, *n* (%)	
NYHA I	179 (59.1)
NYHA II	91 (30)
NYHA III	31 (10.2)
NYHA IV	2 (0.7)
Previous cardiac surgery, *n* (%)	
Ross	31 (10.2)
Others (AV repair, mitral, congenital)	18 (5.9)
Echocardiographic data	
Aortic regurgitation grade, *n* (%)	
AR grade 0–1	102 (33.7)
AR grade 2	72 (23.8)
AR grade 3	88 (29)
AR grade 4	41 (13.5)
LV ejection fraction, *n* (%)	
≥ 50%	255 (84.2)
31–49%	44 (14.5)
≤ 30%	4 (1.3)
VAJ diameter (mm), mean ± SD	26.9 ± 3.6
Root diameter (mm), mean ± SD	48.0 ± 7.6
STJ diameter (mm), mean ± SD	41.9 ± 8.7
Ascending aorta diameter (mm), mean ± SD	42.7 ± 10.2
Maximal aortic diameter (mm), mean ± SD	50.3 ± 8.1

BSA body surface area, *SD* standard deviation, *AR* aortic regurgitation, *NYHA* New York Heart Association, *LV* left ventricle, *VAJ* ventriculo-aortic junction, *STJ* sino-tubular junction. *Aneurysm was defined as aortic diameter ≥ 45 mm and AR grade 0 or 1. Dystrophic AR included AR grade 3 or 4. The mixed group included patients with aneurysm ≥ 45 mm and AR grade ≥ 2

VSRR. Other previous cardiac surgeries included mitral valve repair in 4 (1.3%), isolated AV Repair in 4 (1.3%), aortic root remodeling in 3 (1%), coronary artery bypass grafting (CABG) in 1 (0.3%), and congenital surgery in 6 (2%).

Surgical techniques used are summarized in Table 2. Two patients (0.6%) benefited from VSRR during a second run, due to residual AR after AV repair; the remaining patients had VSRR upon first intention. Cusp repair techniques were used in 163 (53.8%) patients in total, often including more than one leaflet, or more than one technique. Pericardial patch was only used in four (1.3%) of these patients. Additional procedures were performed in 100 (33%) patients. Among patients with Marfan Syndrome, 8 (24%) of them benefited from combined VSRR and mitral valve (MV) repair.

Table 2 Surgical techniques and perioperative outcomes

Surgical techniques	$n = 303$
CPB, mean ± SD	151.9 ± 38.7
CC, mean ± SD	124.6 ± 28.1
Graft size(mm), median	30
Straight graft, (*n* (%), [median])	55 (18%), [23]
Sinus graft (*n* (%), [median])	248 (82%), [23]
Techniques	
Cusp repair, *n* (%)	
Cusp plication	145 (47.9)
Cusp resuspension	42 (13.9)
Patch reconstruction	4 (1.3)
Additional procedures, *n* (%)	
CABG	33 (10.9)
Hemi-arch	14 (4.6)
Mitral valve repair	27 (8.9)
Other	26 (8.6)
Perioperative outcomes (in-hospital)	
Reoperation for bleeding, *n* (%)	26 (8.5)
Pace-maker implantation, *n* (%)	6 (2)
Thromboembolic events (stroke, TIA), *n* (%)	5 (1.7)
In-hospital mortality, *n* (%)	3 (1)
Hospital stay, days, mean ± SD	11 ± 10.6
Discharge AR, median [IQR]	1 [0–1]

CPB cardiopulmonary bypass, *CC* cross-clamp, *SD* standard deviation, *CABG* coronary artery bypass grafting, *TIA* transient ischemic attack, *AR* aortic regurgitation

In-hospital outcomes

Hospital mortality involved three (1%) patients, of which two patients were admitted for urgent TAAD. Excluding TAAD, elective in-hospital mortality was 0.3%. Causes of early death were sudden cardiac arrest, ischemic stroke, and pulmonary infection. Aortic valve repair-related perioperative outcomes are listed in Table 2. None of the patients required early reoperation for repair failure. Other early postoperative complications included stroke in four patients (1.3%) and transient ischemic attack in one (0.3%). Patients were discharged after an average of 11 ± 10.6 days. At discharge, transthoracic echocardiography showed no AR in 86 patients (28%), AR 1+ in 166 (55%) and moderate in 10 (3.3%).

Long-term survival

During the follow-up period, 36 (11.9%) patients died. Among the late deaths, 10 deaths (3.3%) were cardiac-related (4 sudden or unexplained, 5 chronic heart failure and 1 cerebellar hemorrhage) and 26 deaths (8.6%) were non cardiac-related (9 cancer, 7 sepsis, 3 acute type-B aortic dissection, 2 chronic renal failure, 1 ruptured abdominal aortic aneurysm, 1 trauma, 1 bowel ischemia, 1 Parkinson's disease, and 1 general condition deterioration). Overall survival was 99 ± 1%, 92 ± 2%, and 75 ± 5% at 1, 5, and 10 years, respectively. (Fig. 2) Freedom from valve-related death was 99.3 ± 0.5%, 97.4 ± 1.2%, and 96.6 ± 1.4% at 1, 5, and 10 years, respectively.

Overall survival was similar between patients with preoperative AR 0–1+ compared to patients with AR ≥ 2+ (p = 0.864). Ten-year overall survival was 100% in patients operated for dystrophic AR with annuloectasia, 84.3 ± 5.6% in patients with aneurysm and AR 0–1+ and 70 ± 6.4% in patients with aneurism and AR ≥ 2+.

By univariate cox-regression analysis, predictors of death were age (HR, 1.04; $p = 0.003$), NYHA (HR, 1.67; $p = 0.02$), peripheral arteriopathy (HR, 3.37; $p = 0.09$), TAAD (HR, 6.68; $p = 0.001$), CPB time (HR, 1.01; $p = 0.008$), and ACC time (HR, 1.02; $p = 0.008$). In a multivariate model, only age, NYHA, TAAD, and preoperative LVEDD remained significant predictors of death.

Late reoperations

Seventeen (5.6%) patients required AV reoperation during the follow-up period, with a linearized rate of AV reoperation at 0.97% patient-years. Median interval to reoperation was at 4.9 years (IQR: 2.9–6.8 years). Indications for reoperation included recurrent severe AR in 9 (2.97%) patients, endocarditis in 4 (1.3%), mixed AV disease in 3 (1%), and stenosis in 1 (0.3%). Twelve (4%) of the reoperated patients benefited from AV replacement, and the remaining five (1.7%) benefited from AV re-repair. Re-repair were performed only in patients with recurrent AR as indication of reoperation. Freedom from AV reoperation was 100%, 95 ± 2%, and 90 ± 3% at 1, 5, and 10 years respectively (Fig. 3a). Other cardiac reoperations included four MV repairs, one heart transplant for end-stage heart failure, two balloon dilatations of pulmonary homograft, and one right atrium myxoma resection. Freedom from other cardiac reoperation was 99.2 ± 1%, 96 ± 1%, and 95 ± 2%, at 1, 5, and 10 years, respectively.

Freedom from AV reoperation was similar in patients with preoperative AR 0–1+ compared to those with AR ≥ 2+ (94 ± 4.4% vs 88 ± 3.6%, respectively, at 10 years; $p = 0.26$) (Fig. 3b). Figure 3c shows the freedom from reoperation following the surgical indication. In patients operated electively, freedom from reoperation was relatively lower in patients operated for dystrophic AR and annuloectasia compared to the patients operated for root dilatation with or without AR (76.4 ± 15.5% vs 91.4 ± 2.7%, respectively, at 10 years; $p = 0.28$). Freedom from AV reoperation was not influenced by the need of leaflet repair during surgery (90 ± 4% with repair vs 89.3 ± 4.1% without repair at 10 years; $p = 0.708$). (Fig. 3d) Univariate cox-regression analysis of reoperation identified no significant predictors.

Long-term AV repair function

Freedom from severe AR (>2+) was 100%, 96 ± 2%, and 91 ± 4% at 1, 5, and 10 years, respectively, while freedom from moderate to severe AR (> 1+) was 93.7 ± 1.5%, 81.2 ± 2.8%, and 71.5 ± 4.6%. (Figs. 4a, b) Freedom from severe AR (> 2+)

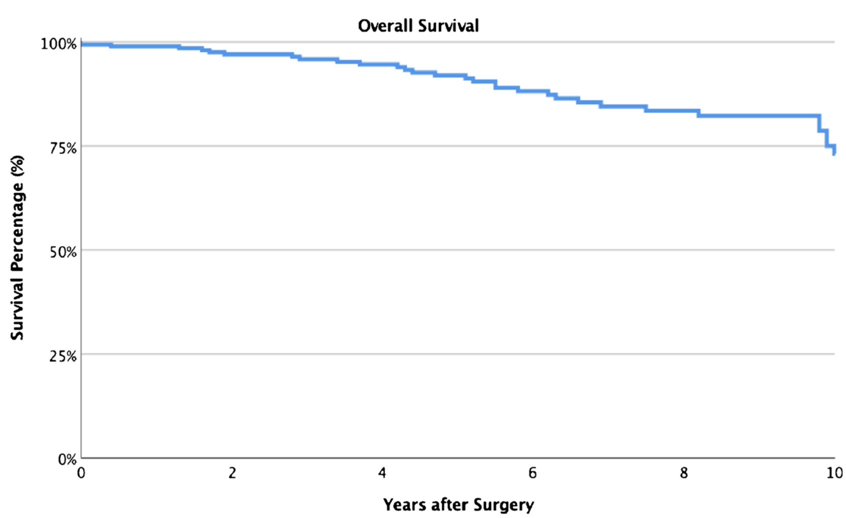

Fig. 2 Overall survival in VSRR at 10 years at 75 ± 5%

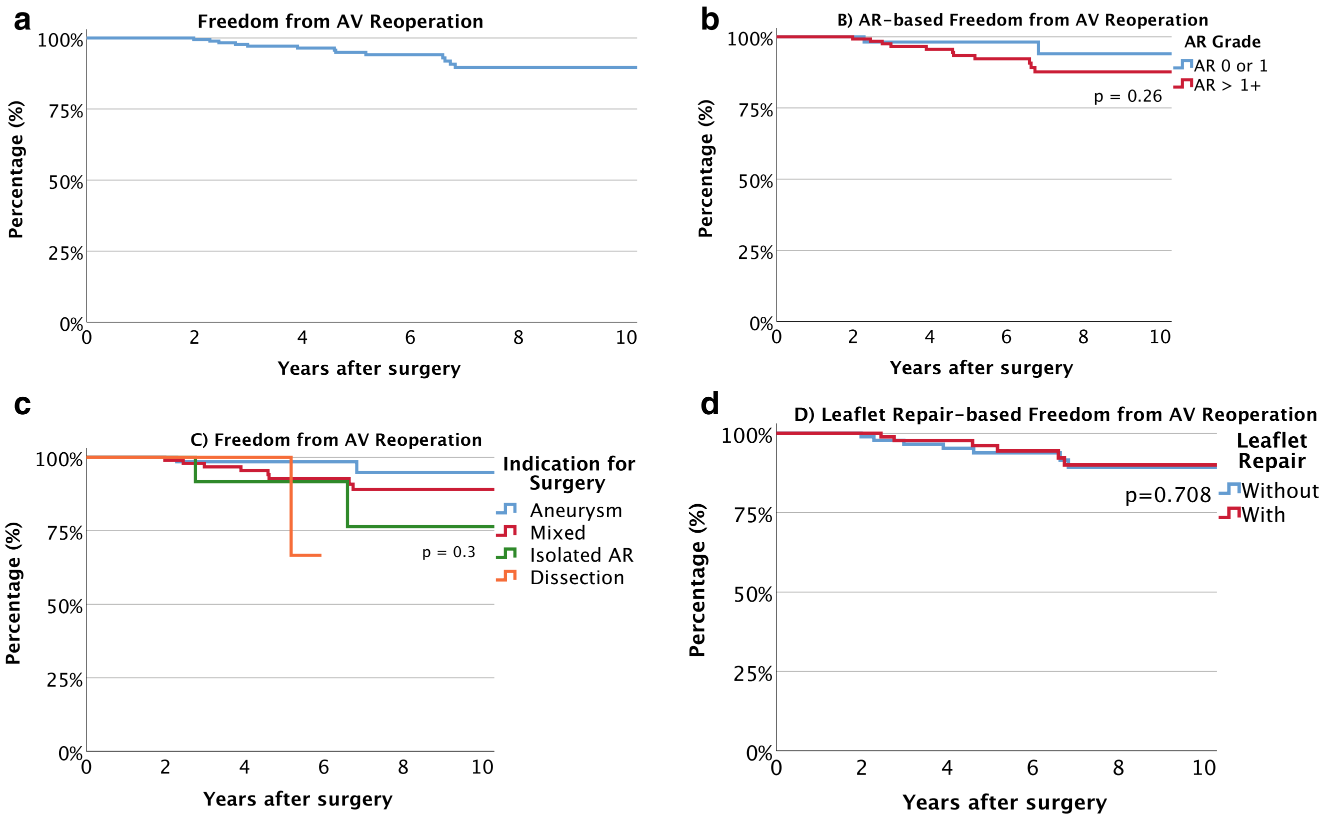

Fig. 3 **a** Freedom from reoperation on the Aortic Valve. At 10 years: 90 + 3%. **b** Freedom from AV reoperation by preoperative AR grade, with no significant difference between the groups ($p = 0.26$). **c** Freedom from AV reoperation by indication for surgery. **d** Freedom from AV reoperation compared between patients who benefited from leaflet repair or not

was very similar for patients who need leaflet repair compared to those who did not need leaflet repair (95.7 ± 2% vs 89.4 ± 5%, $p = 0.88$).

In univariate cox-regression analysis, predictors of AR > 1+ were indication for surgery (indication as a group, HR, 1.6; $p = 0.01$), NYHA (HR, 1.6; $p = 0.02$), previous cardiac surgery (HR, 2.3; p = 0.01), preoperative LVEDD (HR, 1.04; $p = 0.03$), and preoperative AR (HR, 1.7; $p < 0.001$). In a multivariate model, only indication for surgery, previous cardiac surgery, and presence of preoperative AR 2 or 3 remained significant predictors of AR recurrence. These findings correspond well the Kaplan-Meier graph (Fig. 4c) showing a significant increase in risk of AR > 1+ with each increase in preoperative AR grade class ($p = 0.01$). The Kaplan-Meier graph in Fig. 4d also shows the direct implication of indication for surgery, as portrayed in the multivariate model.

Valve-related events

Thromboembolic events occurred in six (2%) patients, with a linearized rate of 0.3% patient-year. Freedom from thromboembolic events was 99.6%, 99 ± 1%, and 98 ± 1% at 1, 5, and 10 years, respectively (Fig. 5a). Freedom from major bleeding event was 98 ± 1% at 1 year and 97 ± 1% at 5 and 10 years (Fig. 5b), with a linearized rate of 0.45% patient-year. Infective endocarditis occurred in five patients (1.7%) with a linearized rate of 0.3% patient-year. Of these patients, four were reoperated as reported earlier, and one refused reoperation and was treated with antibiotics alone. This last patient was still alive at the last clinical follow-up, 1 year after the event, and 12 years after surgery.

Discussion

Undergoing valve-sparing operation, patients benefit from several potential advantages when compared to prosthetic valves. Compared to mechanical prosthesis, these advantages include lack of anticoagulation and its associated risks and reduced risk of infection. Compared to bioprosthetic valves, these advantages include reduced risk of valve deterioration especially in young age, reduced reoperation rate, and enhanced hemodynamic profile.

Like others, we have shown in several previous publications that VSRR is safe and efficient in different clinical situations, including BAV and Marfan syndrome [10–12, 23–33]. This study focuses on our 20-year experience with VSRR in patients with TAV, and we were able to show that preserving the native

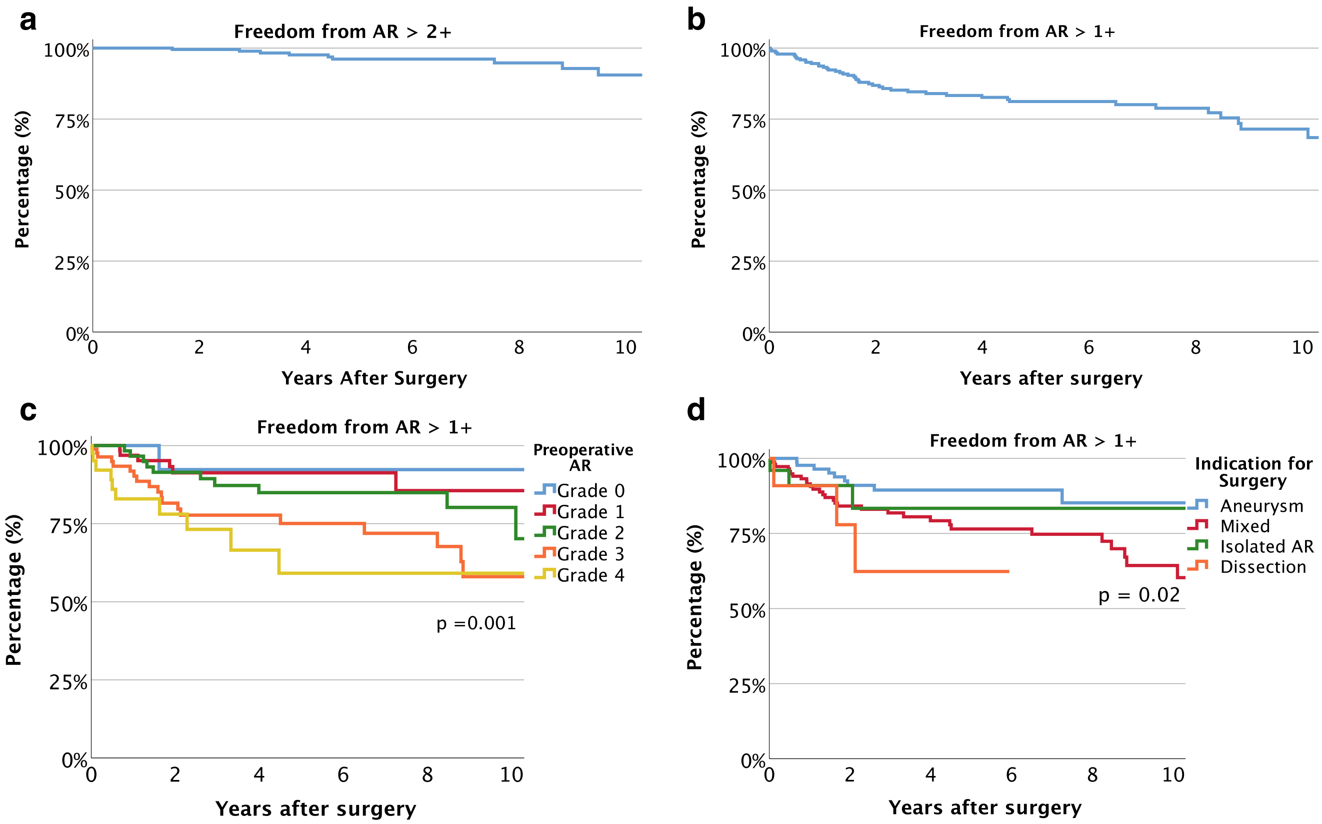

Fig. 4 **a** Freedom from AR > 2+ recurrence. At 10 years, 91 ± 4%. **b** Freedom from AR > 1+ recurrence. At 10 years, 71.5 ± 4.6%. **c** Freedom from AR > 1+ recurrence by preoperative AR grade with very significant difference. At 10 years, 92.3 ± 7.4%, 85.6 ± 6.5%, 80.2 ± 6.6%, 58 ± 8.9%, and 59.1 ± 11.3% for preoperative AR grades 0 through 4 respectively. **d** Freedom from AR > 1+ recurrence by indication for surgery

valve leads to excellent long-term results in terms of survival and reoperation rate. Valve-related events are also very low in VSRR, and our results corroborate those of a recent meta-analysis [34] on outcome after valve-sparing surgery.

When compared to a Bentall procedure, several studies [9, 35, 36], including the ones with propensity-score matching managed to prove significantly fewer thromboembolic and hemorrhagic events in patients operated with VSRR. Reoperation rate however was often higher than in Bentall procedures, with a risk increase between 4-fold and 11-fold. Survival was in general very similar between the two techniques [9], except in Ouzounian et al.'s study [10] where

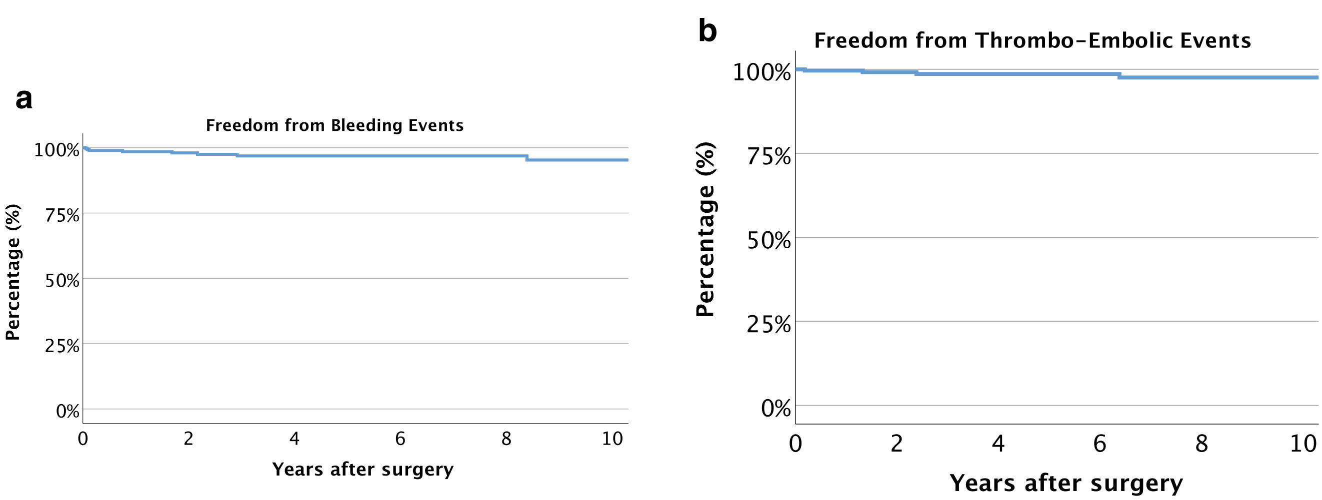

Fig. 5 Freedom from adverse events. **a** Freedom from major bleeding events. At 10 years, 98 ± 1%. **b** Freedom from thromboembolic events. At 10 years, 97 ± 1%

significantly higher mortality was associated with bio-Bentall procedures.

When it comes to survival, our population showed 75% overall survival at 10 years irrespective of presence of preoperative AR or not ($p = 0.864$) and freedom from valve-related death was 97%. Compared to the literature, David et al. [30] showed a survival rate of 89% at 10 years, De Paulis et al. [23] showed 90%, Shrestha et al. [28] at 85%, and Kvitting et al. [37] at 93.5%. Survival after remodeling with Schäfers et al. [38] was 77% at 10 years. This difference in long-term survival is probably explained by the fact that most those studies included patients with TAV but also patients with BAV who are generally younger. Moreover, our cohort includes more patients with previous cardiac surgeries as well as concomitant cardiac procedures.

Freedom from reoperation was established at 90% at 10 years, irrespective of presence of preoperative AR or not ($p = 0.26$). In comparison, this rate in the different studies [23, 28–30, 37, 38], ranged between 84 and 96.9% with David and colleagues [30]. One main difference with this last group could be the disparate inclusion criteria. In our experience, AR 3+ to 4+ was present in 42.5% of the patients and leaflet repair was necessary in more than half the patients, either due to pre-existing prolapse, especially in patients operated for dystrophic AR, or due to VSRR-induced prolapse. Indeed, reducing the aortic dimensions when reimplanting the valve could lead to increased leaflet mobility, and thus eventually to a certain degree of leaflet prolapse. Visual inspection and measure of leaflet effective height after reimplantation is therefore primordial [21].

We would also like to shed light on the specific subgroup of patients operated for dystrophic AR with aortic root dimensions within the "Grey Zone" between 40 and 45 mm. For these cases, VSRR was mainly judged beneficial when intraoperatively, the presence of severe annuloectasia and the aortic wall appeared very thin and translucent due to a developing aneurysmal process. Even though this group showed a slightly higher reoperation rate, they still had an excellent survival rate. This is probably due to the young age of this subgroup, with severe AR and, very often, valves that are technically more difficult to repair due to presence of extensive prolapse sometimes.

A non-negligible portion of our patient cohort (10%) had previously benefited from a Ross procedure, most often using the freestanding root technique. Those patients are prone to autograft dilatation when lacking support and were treated in our institution with VSRR. Those Ross reoperations benefiting from VSRR had a freedom from re-reoperation at 8 years of 81.8%.

VSRR was also performed in patients with TAAD. This situation is usually associated with a higher operative morbidity and mortality [39]. Among our 13 patients operated for TAAD, two had an early death (15.4%) and overall survival at 5 years was 72%. With only one patient requiring reoperation, this subgroup showed an excellent reoperation rate. Performing VSRR in those life-threatening situations mostly aims at preventing long-term complications such as recurrent aortic root dissection, dilatation, false aneurysm from proximal anastomosis, or recurrence of aortic insufficiency. Despite increased mortality and morbidity, we believe that VSRR should be applied in TAAD situations when necessary, especially if performed in expert centers. Several authors have already published on the safety of performing VSRR in acute dissection [40–42].

As for the choice of graft, our initial experience started with straight Dacron graft. Even though several reports demonstrate a good durability of a spared valve into a straight conduit [28], several cases of leaflet abrasion leading to fracture of leaflet retraction and thickening have been reported [43]. For these reasons, the initial DAVID I technique was modified to include neo-sinuses. Several techniques aim to create neo-sinuses like the DAVID V using straight tube graft with plication stitches at the base and at the sino-tubular junction, or the Stanford modification using straight tubes of different size, or finally grafts with built-in sinuses like the Valsalva graft, the Cardioroot (Maquet: Wayne, NJ) or the Sinus graft (Uni-Graft W SINUS; Braun, Melsungen, Germany). Which of these techniques is the most appropriate remains a matter of debate requiring further comparison [4].

Study limitations

Our study has several limitations that should be taken into account. Even though the experience is over 20 years in total, most of our patients were operated on in recent years and therefore median follow-up is short. At 10 years since surgery, only 10% of the initial cohort remain at risk, and thus, only cautious statements about late results can be confirmed. Further, this is a single-center experience with all operations carried out by a very limited number of surgeons; therefore, the results may not be generalizable. Finally, the limited number of adverse events, particularly valve reoperation, precludes any robust statistical analysis for the identification of significant predictors.

Conclusion

Aortic valve-sparing has been performed for over two decades in our institution, and the results in TAV have been excellent in terms of patient survival and freedom from valve-related adverse outcomes including valve reoperation. These results continue supporting the use of VSRR in patients with aortic aneurysm, irrespective of whether they have preoperative AR or not. VSRR is safe, durable, and reproducible, but further follow-up, well into the second decade is still necessary.

Compliance with ethical standards

Conflict of interest none declared for any of the authors.

Source of funding none.

Informed consent This observational study was approved by the Review Ethics Board of Université Catholique de Louvain, and a waiver of consent was obtained.

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