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Aortic root enlargement does not increase the surgical risk and short-term patient outcome?☆

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Abstract

Objective: To analyze the short-term outcome of aortic root enlargement (ARE) using death and adverse events as end points. **Methods:** From January 1999 through December 2009, 3339 patients were subjected to aortic valve replacement (AVR). A total of 678 were considered to have small aortic roots (SARs) in which an aortic prosthesis size 21 mm or smaller was implanted. ARE using a bovine pericardial patch was performed in another 218 patients, who constitute the study population. This comprised 174 females (79.8%); the mean age was 69.4 ± 13.4 years (8–87, median 74 years), the body surface area (BSA) was 1.59 ± 0.15 m^2 and the body mass index (BMI) 25.77 ± 3.16 kg m^{-2}, and 192 (88.5%) were in New York Heart Association (NYHA) II–III. Preoperative echocardiography revealed significant left ventricular (LV) dysfunction in 17 patients (8%), a mean aortic valve area of 0.57 ± 0.27 cm^2, and a mean gradient of 62.51 ± 21.25 mmHg. A septal myectomy was performed in 129 subjects (59.2%), and other associated procedures, mostly coronary artery bypass grafting (CABG), in 60 (27.5%). Bioprostheses were implanted in 161 patients (73.9%). The mean valve size was 21.9 ± 1.0 (21–25). The mean extracorporeal circulation (ECC) and aortic clamping times were 82.8 ± 19.8 min and 56.8 ± 12.5 min, respectively. **Results:** Hospital mortality was 0.9% (n = 2) for ARE as compared with 0.6% (n = 4) for the SAR group (p = 0.8). Inotropic support was required in only 13 (5.9%) patients and the first 24-h chest drainage was 336.2 ± 202 ml. Other complications included pacemaker implantation (7.8%), acute renal failure (10.6%), respiratory (4.1%), and CVA/transient ischemic attack (CVA/TIA) (3.2%). Postoperative echocardiographic evaluation showed a significant decrease in peak and mean aortic gradients (23.7 ± 9.5 and 14 ± 6.2 mmHg, respectively, $p < 0.0001$). The mean indexed effective orifice area (iEOA) was 0.92 ± 0.01 cm^2 m^{-2} (vs 0.84 ± 0.07 cm^2 m^{-2}, in SAR, $p < 0.0001$). Only 11% of patients (n = 24) with ARE exhibited moderate patient–prosthesis mismatch (PPM) and none had severe PPM. Mean hospital stay was 9.7 ± 9.29 days (median 7 days). **Conclusions:** With the growing number of patients with degenerative aortic valve pathology, mainly an older population, sometimes with calcified and fragile aortic wall, the issue of dealing with an SAR poses the dilemma of whether to implant a smaller prosthesis and admit some degree of PPM, or to enlarge the aortic root. This study demonstrates that the latter can be done in a safe and reproducible manner.

Keywords: Aortic valve replacement; Small aortic root; Aortic root enlargement; Patient–prosthesis mismatch

1. Introduction

The main goal of aortic valve replacement (AVR) for aortic stenosis is to alleviate the pressure and volume overload on the left ventricle, allowing remodeling and regression of the ventricular mass. This requires a valve substitute of adequate size for the specific patient. Because the population is aging, the incidence of degenerative aortic valve disease continues to grow and the issue of dealing with a small aortic root becomes frequent. As all prostheses are to some degree obstructive due to sewing rings, struts, and stents, it is not always possible to avoid patient–prosthesis mismatch (PPM) using standard implantation procedures, particularly in small patients and in those with a large body surface area (BSA).

The concept of PPM was created by Rahimtoola [1] to describe the phenomenon in which the effective orifice area (EOA) of the implanted prosthesis may be inadequate for the patient's body size. Subsequently, Pibarot and Dumesnil [2] defined PPM as a prosthetic valve effective orifice area indexed (iEOA) to BSA of 0.85 cm^2 m^{-2} or less. They estimated that it occurs in 19–70% of patients undergoing AVR, and suggested that it might be associated with less regression of left ventricular (LV) hypertrophy, more cardiac events, and lower survival. Others [3,4] have recently corroborated these findings regarding the negative impact of PPM on long-term survival. Ruel et al. [5] found that

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patients with PPM and LV dysfunction experienced not only decreased late survival, but also a lower freedom from heart failure symptoms and a diminished LV mass regression. They found that patients with impaired LV function preoperatively represent a 'critical population' in whom PPM should be avoided.

By contrast, other authors disputed these findings, even in recent reports such as those of Blackstone et al. [6], who concluded that PPM was a rare occurrence after AVR and had a negligible impact with regard to postoperative outcomes, and of Jamieson et al. [7], who found that PPM was not a predictor of overall standard unadjusted mortality up to 15 years after AVR, regardless of the category of iEOA (>0.85 cm^2 m^{-2}; 0.65–0.85 cm^2 m^{-2}; <0.65 cm^2 m^{-2}).

Surgeons have several options available when confronted with the small aortic annulus: to use a small prosthesis (admitting some degree of PPM), to implant a stentless valve or a homograft, or to use a Ross procedure. The last three options, albeit the better ones regarding hemodynamic profiles, are associated with an almost threefold higher operative risk than simple AVR.

There remains the alternative of an aortic root enlargement (ARE). Surgical methods of ARE have long been described [8–10], but surgeons are still reluctant to perform it, probably influenced by initial reports of higher mortality [11], and by the small number of patients included in the studies published. We have used patch enlargement of the aortic annulus routinely and have found this technique to be particularly attractive and straightforward, allowing implantation of a one- or two-size larger prosthetic valve.

In this work, we present our surgical results and analyze the short-term mortality and morbidity of patients who had ARE, comparing this population to a cohort of patients with small aortic roots (SARs), who had isolated or combined AVR without root enlargement.

2. Material and methods

2.1. Patient population

From January 1999 through December 2009, 3339 patients were subjected to isolated or combined AVR at our institution. A total of 218 patients (6.5%) were submitted to trans-annular ARE with a bovine pericardial patch. This is the study group and does not include patients who had supra-annular enlargement to facilitate closure of a calcified aortic wall or an otherwise complicated aortotomy. Another 678 patients (20.3%) were considered to have SARs in which an aortic prosthesis of size 21 mm or smaller was implanted using the classical technique, without enlargement of the root, and serve as the control group. Patients receiving concomitant coronary artery bypass grafting (CABG) surgery and other surgical procedures were included in both groups.

Prosthesis type and size were documented in all patients. The mean age of the ARE population was 69.4 ± 13.4 years (8–87 years, median 74 years), 174 were female (79.8%), 192 were in New York Heart Association (NYHA) class II–III (88.5%), and 21 were redo procedures (9.6%). Table 1 summarizes the baseline demographic and clinical characteristics of these patients. The surgical indications for AVR were stenosis (156 patients; 71.6%), mixed lesion (47; 21.6%), insufficiency (14; 6.4%), and one case of dysfunction of aortic prosthesis. Preoperative echocardiographic findings revealed significant LV dysfunction in 17 patients (8%), a mean aortic valve area of 0.6 ± 0.3 cm^2, and a mean aortic gradient of 62.5 ± 21.2 mmHg.

Table 1. Characteristics of the study population.

Variable	ARE *n* (%)	SAR *n* (%)	*p*-value
Age (years)	69.4 ± 13.4	70.0 ± 9.6	0.564
Sex (female)	174 (79.8%)	602 (88.6%)	0.001
Body surface area (m^2)	1.59 ± 0.2	1.56 ± 0.1	0.084
Body mass index (kg m^{-2})	25.77 ± 3.2	24.82 ± 2.7	0.320
NYHA class > II	192 (88.5%)	641 (94.5%)	0.279
Previous cardiac surgery	21 (9.6%)	49 (7.2%)	0.413
Chronic atrial fibrillation/flutter	27 (12.4%)	184 (27.1%)	0.245
Hypertension	123 (56.4%)	283 (41.7%)	0.040
Diabetes mellitus	38 (17.4%)	98 (14.5%)	0.210
Coronary disease	57 (26.1%)	153 (22.5%)	0.273
Previous myocardial infarction	8 (3.7%)	17 (2.5%)	0.290
Previous CVA/TIA	12 (5.5%)	21 (3%)	0.451
Valve pathology			
Insufficiency	14 (6.4%)	44 (6.5%)	0.968
Stenosis	156 (71.6%)	473 (69.7%)	0.594
Mixed	47 (21.6%)	161 (23.7%)	0.682
Other	1 (0.4%)	–	–
Euroscore (additive)	5.2 ± 2.4	4.9 ± 2.5	0.299
Echocardiographic findings			
LV dysfunction (EF < 45%)	18 (8.3%)	23 (5.2%)	0.121
IVS (mm)	14.3 ± 2.3	–	–
LVPWT (mm)	11.7 ± 1.9	–	–
Aortic valve area (cm^2)	0.6 ± 0.3	0.5 ± 0.2	0.165
Peak gradient (mmHg)	94.7 ± 29.3	90.8 ± 27.8	0.117
Mean gradient (mmHg)	62.5 ± 21.3	61.6 ± 19.8	0.735

ARE: aortic root enlargement; CABG: coronary artery bypass grafting; EF: ejection fraction; LV: left ventricle; IVS: interventricular septum; and LVPWT: left ventricular posterior wall thickness.

2.2. Operative technique and data

The operative technique of AVR was standard for all patients and included cardiopulmonary bypass (CPB) with moderate hypothermia (28–30 °C), topical cooling with ice slush, and intermittent antegrade cold crystalloid cardioplegia, either in the aortic root or directly in the coronary ostia, depending on the competence of the aortic valve. The aortotomy was made in an oblique fashion ('hockey stick'). Once the aortic valve was excised and the annulus debrided, valve selection and sizing were performed with the sizers provided by the respective manufacturers.

The technique used for ARE has been previously described [10]. The aortic incision is extended into the middle of the non-coronary sinus, through the aortic annulus and into the anterior margin of the fibrous mitro-aortic curtain, 10–15 mm below the aortic annulus. Only seldom do we enter the roof of the left atrium because the atrial wall can be easily separated from the aorta. This is sufficient to allow implantation of a prosthesis one to two sizes larger than initially measured. We usually place the valve sutures in the annulus of the left and right coronary sinuses before implanting a tear-drop-shaped glutaraldehyde-treated bovine pericardium patch, which is sewn with a single running 4/0 polypropylene suture, starting at the nadir of the root incision and continued each side to about 1 cm above annular level. The root is resized and the appropriate valve is

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chosen. Pledgeted sutures are passed from outside the patch to the lumen to complete the circular line of valve implantation. The sutures are then passed through the prosthesis and tied, and closure of the aortotomy is completed, trimming the pericardium as required for a correct geometry.

A septal myectomy (below the commissure between left and right coronary sinuses) was performed routinely in aortic stenosis as an additional means to relieve the subvalvular obstruction component of these hypertrophied ventricles (mean interventricular septum thickness (IVS) = 14.3 ± 2.3 mm). We generally take a generous piece of myocardial septum (2–3 cm long, 1–2 cm wide, and 0.5–0.7 cm deep).

2.3. Assessment of PPM

The iEOA was calculated dividing the published *in vivo* EOA value [2] by the patient's BSA at the time of the operation, available for all patients. PPM was defined as minimal for an iEOA greater than 0.8 $cm^2\ m^{-2}$, moderate for an iEOA of 0.65–0.8 $cm^2\ m^{-2}$, and severe for an iEOA less than 0.65 $cm^2\ m^{-2}$.

2.4. Statistical analysis

Data were retrospectively collected from the clinical records, operative reports, and preoperative complementary exams. Perioperative analysis included assessment of 30-day mortality (in- and out of hospital) and adverse events related to the surgical procedure.

Data are presented as frequency distributions and simple percentages. Continuous variables are expressed as mean ± standard deviation (SD) and categorical variables as percentages. Continuous data were compared between groups using unpaired two-tailed Student's *t*-tests for parametric data and Wilcoxon rank-sum tests for non-parametric data. Categorical data were compared between groups using a Fisher's exact test. Statistical significance was considered for a *p*-value less than 0.05.

3. Results

Patients with ARE were slightly younger than patients with SAR (69.4 ± 13.4 years vs 70.0 ± 9.6 years; $p = 0.56$), had less female patients (88.6% vs 79.8% $p = 0.001$), and a predominance of bioprostheses implanted (73.9%, $p < 0.0001$), while SAR had a balanced distribution of type of prosthesis (mechanical, 47.9% vs biological, 52.1%). With regard to the distribution of co-morbidities between both groups, only the prevalence of hypertension was significantly higher in the ARE group ($p < 0.05$). Table 2 shows the operative details, including associated procedures and the type of valves implanted. We stress the high number of septal myectomies performed ($n = 129$, 59.2%) compared with that described in other ARE series [18]. In 44 patients (20.1%), heavily calcified aortic root and proximal ascending aorta (not porcelain aorta) was observed. CPB and cross-clamp times were appreciably longer in the ARE group, adding 13.3 and 10.4 min ($p < 0.0001$), respectively, to the AVR procedure.

The distribution of labeled aortic prostheses sizes is depicted graphically in Fig. 1. As most of the AREs were done in the context of SARs and in a predominantly female population with small stature (mean BSA = 1.59 ± 0.2 $cm^2\ m^{-2}$), the median prosthesis size implanted was 21, even after an aortic enlargement, which means that we were dealing with a very small annulus, 19 mm or less. Unfortunately, we do not have the intra-operative native annulus measurements to correlate with the extent of upsizing made with the ARE.

Associated procedures, mostly CABG, were carried out in 60 patients (27.5%) in the ARE group and in 221 (32.6%, p = NS) in the SAR group. As referred above, supra-annular aortic root enlargement was done in 69 patients (10.2%) in the SAR population, either to facilitate closure of the aortotomy (in calcified aorta) or to elude direct contact between bioprosthesis struts and the arterial wall.

We analyzed the prevalence of PPM in our study population (Table 3), and documented that minimal or no PPM was achieved in the majority of patients (88.1%) with a mean iEOA of 0.91 $cm^2\ m^{-2}$, Moderate PPM was present in

Table 2. Operative and prosthetic valve characteristics.

Variable	ARE *n* (%)	SAR *n* (%)	*p*-value
CBP duration (min)	82.8 ± 19.8	69.5 ± 20.3	<0.0001
Aortic clamp duration (min)	56.8 ± 12.5	46.4 ± 14.1	<0.0001
Concomitant procedures	60 (27.5%)	222 (32.7%)	0.064
CABG	33 (15.1%)	94 (13.9%)	
Mitral repair/replacement	16 (7.3%)	87 (13.8%)	
Tricuspid annuloplasty (modified De Vega)	5 (2.3%)	36 (5.3%)	
Others	6 (2.8%)	86 (12.7%)	
Septal myectomy	129 (59.2%)	443 (65.3%)	0.144
Stented bioprostheses	161 (73.9%)	352 (52.1%)	<0.0001
Edwards porcine	144 (66.1%)	303 (44.7%)	
St. Jude Epic	17 (7.8%)	49 (7.2%)	
Other	–	1 (0.1%)	
Mechanical valves	56 (25.7%)	324 (47.9%)	<0.0001
Medtronic-Hall	52 (23.9%)	295 (43.5%)	
St. Jude	4 (1.8%)	27 (4.0%)	
Other	–	3 (0.4%)	
Pulmonary autograft	1 (0.5%)	–	

ARE: aortic root enlargement; SAR: small aortic root (no trans-annular enlargement included); CABG: coronary artery bypass grafting; and CPB: cardiopulmonary bypass.

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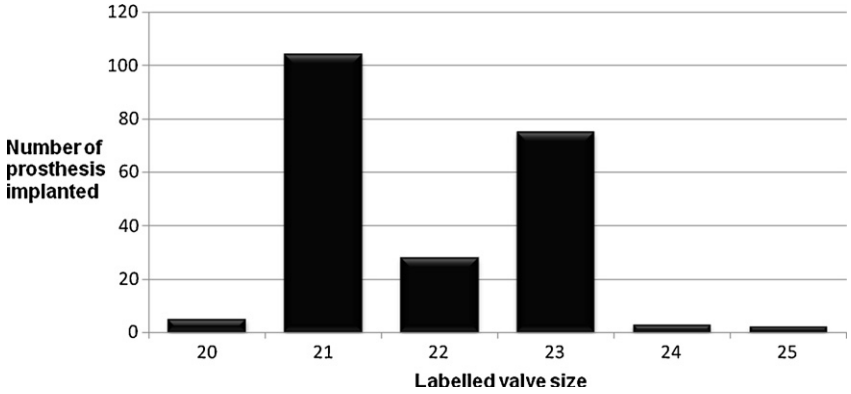

Fig. 1. Labeled valve size distribution in the ARE population (sizes 20, 22 and 24 are exclusive of the Medtronic-Hall valve).

11.1% (mean iEOA = 0.76 $cm^2\ m^{-2}$), and there were no cases of severe PPM. As expected, the SAR group had a lower iEOA ($0.84 \pm 0.07\ cm^2\ m^{-2}$, $p < 0.0001$), but moderate PPM was only present in 22% of patients, most likely because of the low threshold for enlargement.

Table 4 shows the perioperative outcomes after ARE. Despite natural longer extracorporeal circulation (ECC) and cross-clamp times, inotropic support was only required in 13% (29) of patients. Chest drainage in the first 24 h was 336.2 ± 202 ml, and only two cases required re-operation for bleeding (0.9%). The rate of neurological accidents was 3.2% (seven), and in 7.8% (17) of the individuals was there need for a permanent pacemaker, in most cases for complete atrioventricular (AV) block.

Hospital mortality was higher in the ARE group (0.9% vs 0.6% in SAR, $p > 0.05$), but the 30-day mortality was similar (1.8% ($n = 4$ patients) in the ARE group and 1.8% (12 patients) in the SAR group, $p = 0.83$). Length of hospital stay was similar in the two groups (9.7 ± 9.29 vs 9.0 ± 2.1 days, $p > 0.05$).

Fig. 2 shows the evolution of ARE procedures performed during the study period, showing a clear trend toward an increasing number of procedures per year, which is in consonance with the team's growing experience and comfort with the technique.

4. Discussion

Calcic aortic stenosis has become the most frequent type of valve heart disease in Europe and North America and is considered severe, hence with indication for surgery, when the valve area is less than 1 cm^2 or, indexing to BSA (iEOA), less than 0.6 $cm^2\ m^{-2}$ [12]. This is usually associated with a mean aortic gradient above 50 mmHg. It is clear that transaortic gradients increase exponentially as the iEOA

Table 3. Indexed prosthetic valve sizing and prosthesis–patient mismatch (PPM).

Variable	ARE *n* (%)	SAR *n* (%)	*p*-value
Mean labeled size (range [median])	21.88 ± 1.03 (21–25 [21])	20.70 ± 0.46 (20–21 [21])	<0.0001
Mean iEOA ($cm^2\ m^{-2}$)	0.92 ± 0.01	0.84 ± 0.07	<0.0001
Minimal PPM	194 (88.9%)	529 (78.1%)	<0.0001
Moderate PPM	24 (11.1%)	149 (21.9%)	<0.0001
Severe PPM	0 (0.0%)	0 (0.0%)	–

iEOA: indexed effective orifice area; PPM: prosthesis–patient mismatch; minimal PPM: iEOA greater than 0.8 $cm^2\ m^{-2}$; moderate PPM: iEOA of 0.65–0.8 $cm^2\ m^{-2}$; severe PPM: iEOA of less than 0.65 $cm^2\ m^{-2}$; ARE: aortic root enlargement; and SAR: small aortic root.

Table 4. Perioperative outcomes of ARE.

Variable	ARE *n* (%)	SAR *n* (%)	*p*-value
Inotropic support (postoperative)	29 (13.3%)	48 (7.1%)	0.004
CVA/TIA	7 (3.2%)	26 (3.8%)	0.673
Re-operation for bleeding	2 (0.9%)	5 (0.7%)	0.792
Chest drainage (ml)	336 ± 202	295 ± 210	0.610
Respiratory complications	9 (4.1%)	26 (3.8%)	0.843
Acute renal failure (creatinine > 2 mg dl^{-1})	23 (10.6%)	58 (8.5%)	0.368
Permanent pacemaker	17 (7.8%)	37 (5.5%)	0.216
Antiplatelet therapy	144 (66.7%)	315 (46.7%)	<0.001
Anticoagulant therapy	74 (34.3%)	358 (53%)	<0.001
Length of hospital stay (days)	9.7 ± 9.29	9.0 ± 5.0	0.642
Mortality			
Hospital	2 (0.9%)	4 (0.6%)	0.10
30-day	4 (1.8%)	12 (1.8%)	0.83

ARE: aortic root enlargement.

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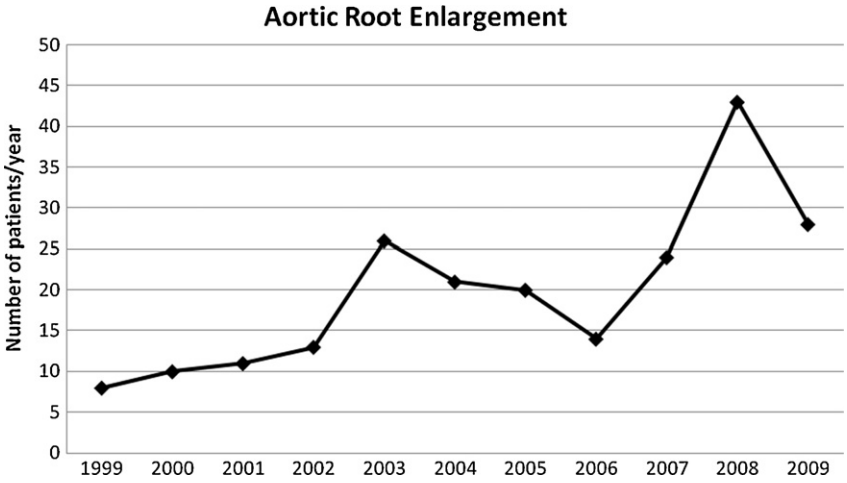

Fig. 2. Evolution of ARE procedures during the study period.

decreases to less than 0.8 $cm^2\ m^{-2}$. The majority of these patients have a reasonable expected survival, as long as they remain asymptomatic. Once symptoms develop, the prognosis changes dramatically, with a 2-year survival rate <50%.

It is intuitive that an operation performed to relieve valve stenosis should leave the patient with the least possible residual obstruction to flow. LV hypertrophy, a known consequence of aortic stenosis, has been strongly correlated with increased risk of sudden death, congestive heart failure, stroke, myocardial infarction, and cardiovascular mortality, as shown by the Framingham study [13]. Hypertrophied hearts, especially those that have an eccentric hypertrophy extending into the LV outflow tract, are prone to residual subvalvular obstruction that may not be completely resolved with implantation of prosthesis. Therefore, our approach in these patients is to treat both valvular and subvalvular stenosis, having a low threshold for performing a septal myectomy (59.2% in the study population). Our low postoperative gradients, even considering the high number of bioprostheses implanted, may be partly related to the liberal use of the myectomy (Fig. 3).

Although the concept of PPM was introduced a long time ago, there remains no consensus about its impact on clinical outcome. Furthermore, there remains no standardized and universally accepted method for the calculation of PPM. In most studies, PPM is anticipated by reference tables, based on mean EOAs as opposed to individual assessment. These reference values may not reflect the actual *in vivo* EOA; hence, the presence or absence of PPM may be based on false assumptions. Others use the indexed geometric orifice area (GOA), but we now know that there is a poor correlation between the GOA and postoperative gradients. *In vitro* EOA values are given by the manufacturer and tend to overestimate the size of the orifice. Individual echocardiographic EOA measurements might more accurately account for interindividual variety in the EOA of patients.

There is currently a trend toward the use of bioprostheses instead of mechanical valves in younger patients, but the former are associated with poorer hemodynamics in the small sizes. Recently, Flameng et al. [14] found that PPM and label size <21 mm were independent predictors of structural valve deterioration (SVD) in tissue valves. They concluded that stenosis-related SVD is an early PPM-related, and thus preventable, phenomenon.

All these data support the clinical relevance of PPM, which raises the question of how we can avoid it. Pibarot and Dumesnil [15] demonstrated that aortic PPM can largely be avoided by systematically calculating the projected iEOA of the prosthesis to be inserted (table charts in the operating room (OR)) and, in the case of anticipated PPM, by using

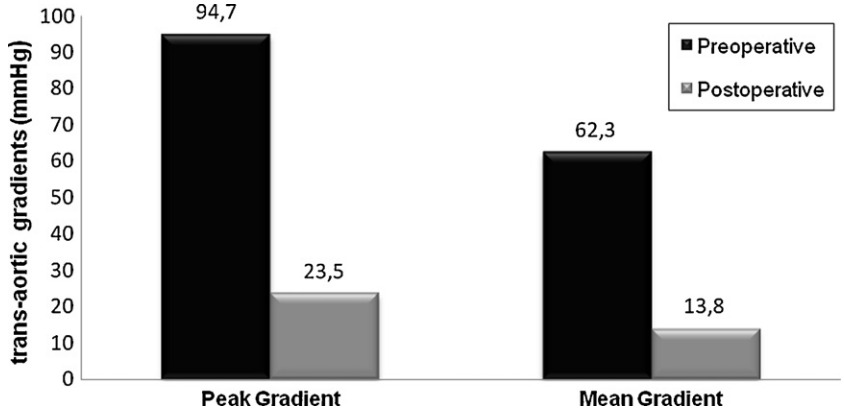

Fig. 3. Transaortic gradients before and after surgery (ARE group).

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Table 5. Comparison of mortality (*Series of isolated AVR; ¥Series of ARE).

Variable	Hospital mortality *n* (%)	30-day mortality *n* (%)
STS database, 2009 [22]*	–/108,687 (2.6%)	–
UKCSR, 2007 [23]*	–/82,797 (3.6%)	–
EHS, 2003 [24]*	–	–/631 (2.7%)
Italian Regional Registry, 2010 [25]*	29/2256 (2.2%)	–
Castro, Gaudiani et al., 2002 [19]¥	1/114 (0.9%)	1/114 (0.9%)
Peterson, David et al., 2007 [18]¥	–/669 (2.9%)	–
Dhareshwar, Orzulak et al., 2007 [16]¥	14/249 (5.6%)	–
Kulik, Ruel et al., 2008 [20]¥	12/172 (7%)	–
Current series (SAR), 2010*	4/678 (0.6%)	12/678 (1.8%)
Current series (ARE), 2010¥	2/218 (0.9%)	4/218 (1.8%)

STS: Society of Thoracic Surgeons (from Brown et al. [22]); UKCSR: United Kingdom Cardiac Surgical Register (from Kalkat et al. [23]); EHS: Euro Heart Survey (from Lung et al. [24]); Regional Registry (Regione Emilia Romagna Interventi Cardiochirurgia, from Eusanio et al. [25]).

alternative procedures, such as insertion of a prosthesis model with better hemodynamic performance or aortic root enlargement to accommodate a larger size of the same model of prosthesis.

Hence, surgical management of the SAR remains a relevant topic, with reports demonstrating superior LV mass regression, postoperative functional class and exercise tolerance, and patient survival when small prostheses are avoided [3,16]. Our preference is for enlargement of the annulus with a patch. This can be done either by anterior (Konno-Rastan) [17] or by posterior enlargement. The former is rarely used in the adult population because of its high complexity, which leaves the latter as the preferred one.

Although ARE procedures have been described for more than 30 years, it has not attracted wide acceptance, and it is practiced by only a few surgical groups. The largest series of patients published ($n = 669$) belongs to the Toronto group [18]. In their first report (1997), they have shown that ARE increased the cross-clamp time by 11 min, the rate of re-operation for bleeding (10.2% vs 6.7%), and the operative mortality rate (7.2% vs 3.5%), compared with patients who underwent AVR alone [11]. Interesting, though, both groups of patients showed similar long-term survival. After this initial negative experience, this group presented new results in 2007, revealing a steeper decline in the mortality rate (down to 2.9%), probably a result of the growing experience. We have also had this 'learning curve', starting with few cases per year and currently performing more than 30 ARE per year (15% of the total AVR procedures).

The work of Castro et al. [19] renewed the interest in ARE because these authors showed an outstanding 30-day mortality rate (0.9%), a low morbidity, and an insignificant rate of PPM (2.6%) in their study population ($n = 114$). CPB time emerged as the only independent predictor of mortality. This, however, can be minimized, as our experience shows.

Recently, the Mayo Clinic group has also published their surgical results [16]. They also did not find the procedure to be a risk factor for operative death. Nevertheless, advanced functional class, preoperative congestive heart failure, and small valve implant size were considered independent risk factors for operative mortality. However, there were no clear indications for ARE, a great variability existing among different surgeons, also with the techniques applied, and there was often not a true trans-annular enlargement. Instead, these authors slightly tilted the prosthesis such that the sewing ring rides above the native annulus. Finally, they had an important number of size 19 prostheses implanted, which, in their large patients (mean BSA = $1.92 \pm 1.20\ cm^2\ m^{-2}$), resulted in low iEOA. Tilting the prosthesis may also create unfavorable hemodynamic conditions.

Kulik et al. [20], also evaluated the effect of ARE on the incidence of postoperative PPM and late clinical outcomes, comparing with patients with SAR. They concluded that PPM (moderate in 42% of their cases) did not significantly impact long-term outcomes after surgery. In our experience, there was only 11% of moderate mismatch and no severe PPM, and it is the latter group that is usually linked to worse outcomes.

We had a low rate of re-operation for bleeding (0.9%) and need for permanent pacemaker (7.8%) compared with others [16,18–21], but an unusual high percentage of acute renal failure (10.6%), although no patient required dialysis. One explanation for this occurrence could be the advanced age compared with the other ARE series.

Finally, when we compare our ARE mortality (Table 5) either with the control group or with the published isolated AVR mortality (Society of Thoracic Surgeons (STS) database, UK register, Euro Heart Survey (EHS) on valvular heart disease), we can conclude that this procedure does not increase early mortality ($p = 0.83$), as had already been documented in recent reports [16,18].

Despite being the third largest series of ARE in the literature, to our knowledge, our study has some limitations. Data were collected retrospectively; thus, some events could have been lost. Further, although it was not the scope of the study, it would have been important to determine the impact of ARE in long-term outcomes to evaluate consistently the benefit of the procedure. Nevertheless, we believe that this study shows that ARE is a valuable and reproducible technique when dealing with an SAR, with low mortality and acceptable morbidity. PPM was largely avoided, and satisfactory iEOAs were achieved. In our hands, as in other surgical centers with significant experience with this procedure, short-term complications were not significantly different from those observed in standard AVR procedures.

References

[1] Rahimtoola SH. The problem of valve prosthesis–patient mismatch. Circulation 1978;58:20–4.
[2] Pibarot P, Dumesnil JG. Hemodynamic and clinical impact of prosthesis–patient mismatch in the aortic valve position and its prevention. J Am Coll Cardiol 2000;36:1131–41.

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[3] Mohty D, Dumesnil JG, Echahidi N, Mathieu P. Impact of prosthesis–patient mismatch on long-term survival after aortic valve replacement: Influence of age, obesity, and left ventricular dysfunction. J Am Coll Cardiol 2009;53:39–47.
[4] Bleiziffer S, Ali A, Hettich IM, Akdere D, Laubender RP, Ruzicka D, Bohem J, Lange R, Eichinger W. Impact of the indexed effective orifice area on mid-term cardiac-related mortality after aortic valve replacement. Heart 2010;96:865–71.
[5] Ruel M, Al-Faleh H, Kulik A, Chan KL, Messana TG, Burwash G. Prosthesis–patient mismatch after aortic valve replacement predominantly affects patients with preexisting left ventricular dysfunction: effect on survival, freedom from heart failure, and left ventricular mass regression. J Thorac Cardiovasc Surg 2006;131:1036–44.
[6] Blackstone EH, Cosgrove DM, Jamieson WR, Birkmeyer NJ, Lemmer JH, Miller DC, Butchart EG, Rizzoli G, Yacoub M, Chai A. Prosthesis size and long-term survival after aortic valve replacement. J Thorac Cardiovasc Surg 2003;126:783–93.
[7] Jamieson WRE, Ye J, Higgins J, Cheung A. Effect of prosthesis–patient mismatch on long-term survival with aortic valve replacement: assessment to 15 years. Ann Thorac Surg 2010;89:51–9.
[8] Nicks R, Cartmill T, Bernstein L. Hypoplasia of the aortic root: the problem of aortic valve replacement. Thorax 1970;25:339–46.
[9] Manouguian S, Seybold-Epting W. Patch enlargement of the aortic valve ring by extending the aortic incision to the anterior mitral leaflet. J Thorac Cardiovasc Surg 1979;78:402–12.
[10] Kinsley RH, Antunes MJ. Enlargement of the narrow aortic root and oblique insertion of a St. Jude prosthesis. Br Heart J 1983;50:330–2.
[11] Sommers KE, David TE. Aortic valve replacement with patch enlargement of the aortic annulus. Ann Thorac Surg 1997;63:1608–12.
[12] Vahanian A, Baumgartner H, Bax J, Butchart E, Dion R, Filippatos G, Flachskamp F, Hall R, Lung B, Kasprzak, Nataf P, Tornos P, Torracca L, Wenink A. ESC 2007 Guidelines on the Management of Valvular Heart Disease. The Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology. Eur Heart J 2007;28:230–68.
[13] Levy D, Garrison R, Savage D, Kannel W, Castelli W. Left ventricular mass and incidence of coronary artery disease in an elderly cohort: The Framingham heart study. Ann Intern Med 1989;110:101–7.
[14] Flameng W, Herregods MC, Vercalsteren M, Herijgers P, Bogaerts K, Meuris B. Prosthesis–patient mismatch predicts structural valve degeneration in bioprosthetic heart valves. Circulation 2010;121:2123–9.
[15] Pibarot P, Dumesnil J. Prosthetic heart valves: selection of the optimal prosthesis and long-term management. Circulation 2009;119:1034–48.
[16] Dhareshwar J, Sundt III TM, Dearani JA, Schaff HV. Aortic root enlargement: what are the operative risks? J Thorac Cardiovasc Surg 2007;134:916–24.
[17] Konno S, Imai Y, Lida Y, Nakajima M, Tatsuno K. A new method for prosthetic valve replacement in congenital aortic stenosis associated with hypoplasia of the aortic ring. J Thorac Cardiovasc Surg 1975;70:909–17.
[18] Peterson MD, Borger MA, Feindel CM, David TE. Aortic annular enlargement during aortic valve replacement: improving results with time. Ann Thorac Surg 2007;83:2044–9.
[19] Castro LJ, Arcidi MJ, Fisher AL, Gaudiani VA. Routine enlargement of the small aortic root: a preventive strategy to minimize mismatch. Ann Thorac Surg 2002;74:31–6.
[20] Kulik A, Al-Saigh M, Chan V, Masters RG. Enlargement of the small aortic root during aortic valve replacement: is there a benefit? Ann Thorac Surg 2008;85:94–101.
[21] Sakamoto Y, Hashimoto K, Takakura H, Ishii S, Taguchi S, Kagawa H. Prevalence and avoidance of patient–prosthesis mismatch in aortic valve replacement in small adults. Ann Thorac Surg 2006;81:1305–9.
[22] Brown JM, O'Brien SM, Wu C, Sikora JA. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: changes in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. J Thorac Cardiovasc Surg 2009;137:82–90.
[23] Kalkat MS, Edwards MB, Taylor KM, Bonser RS. Composite aortic valve graft replacement. Mortality outcomes in a national registry. Circulation 2007;116 Supplement 1:301–6.
[24] Lung B, Baron G, Butchart EG, Delahaye F, Gohlke-Bärwolf C, Levang OW. A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease. Eur Heart J 2003;24:1231–43.
[25] Eusanio M, Fortuna D, Palma R, Dell'Amore A, Lamarra M, Contini G, Gherli T, Gabbieri D, Ghidoni I, Cristell D, Zussa C, Pigini F, Pugliese P, Pacini D, Bartolomeo R. Aortic valve replacement: results and predictors of mortality from a contemporary series of 2256 patients. J Thorac Cardiovasc Surg 2010 [Epub ahead of print].

Appendix A. Conference discussion

Dr T. Fayers (*Queensland, Australia*): Your group has shown that you can take operative mortality of AVR down to below 2%, and show that this remains the gold standard. So the questions are simple really. The first one is, how did you really select your patients for the root enlargement group? I get the impression you mentioned that the small early group of patients had a 21 mm, or smaller, prosthesis implanted, and I think therefore it means some of those probably should have had a root enlargement as well. Does this reflect that senior surgeons started off and has given the group more confidence to do this?

Dr Coutinho: Do you mean the indications?

Dr Fayers: No. How did you select the patients for root enlargement, because in your small group, which you didn't root enlarge, you said that some of your prostheses were under 21 mm in size.

Dr Coutinho: We also used the Medtronic 20 mm prosthesis. You can see the patient characteristics. The small aortic root group had a body surface area smaller than the aortic root enlargement. But the rate of PPM even in the small aortic root was only 22%. So it is a question of options for the surgeon.

Dr Fayers: I just wasn't sure about your suture technique. I understand the pledgets outside the pericardium. What do you do in the rest? Is it simple interrupted or annulus inversion as well?

Dr Coutinho: Interrupted.

Dr Fayers: And then, lastly, we analyzed our series and, much to my surprise, found that in over 700 patients we only had 12 patients that required a 19 mm valve. I think the most likely reason is the fact that you are seeing a smaller population group, and you probably agree on that, but could it also maybe reflect excision of the valve? In Australia, for example, when we look at our results compared to other units, we are implanting bigger valves than they are, and could this be a technical issue that we are just more aggressive in debriding the root or do you think your case is simply smaller patients?

Dr Coutinho: Smaller patients. When you compare our group of aortic root enlargement with other groups, our patients had a significantly smaller body surface area. Our patients had 1.6 cm^2, whereas the group from Toronto, for example, had 1.85, from the Mayo, 1.9. So they were small stature patients.

Dr M. Jasinski (*Katowice, Poland*): You and your group have taken measures to reduce patient–prosthesis mismatch. As we know, that has a very poor influence on the long-term outcome after the Magdi paper from this year, and what we have witnessed from today's presentations, and the question is technical.

Historically, groups doing aortic root enlargement start with the technique of pericardial patch. Have you considered using prosthetic material, the Dacron graft, instead?

Dr Coutinho: We are used to the bovine pericardial patch in other situations, including in congenital surgery, and even in the small aortic root we performed supra-annular enlargement in those groups, and we still used the bovine pericardial patch.

Dr F.C. Riess (*Hamburg, Germany*): My approach is exactly the same, with a myectomy and with a patch and the felt outside. We use an autologous patch fixed with glutaraldehyde and are very satisfied; we have used it for many, many years. What is your approach for the suture line within the patch, what is the distance, where do you start? Is it directly very low to the mitral valve or is it a little bit elevated? We do it so.

Dr Coutinho: Very low to the base of the mitral valve.

Dr Riess: We elevate it a little bit, some millimeters higher.

Dr Coutinho: If you go down, you can get a little bigger distance.

Dr Riess: We feel if you elevate a little bit extra-anatomically within this pericardial patch, you pull up the valve and you have a more central jet into the aorta, because in aortic stenotic patients very often you have a kinking of the valve area and by bringing it a little bit up in the pericardial patch you have.

Dr Coutinho: But you can do the same when you pass the sutures in the patch. We usually pass the sutures in a curvilinear way. We go from one commissure to the other commissure, and then align the prosthesis.

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