Cardiovascular Topics

Investigation of left ventricular changes according to valve type in patients with surgical replacement due to isolated aortic stenosis

Abdullah Güner, Mehmet Işık, Ömer Tanyeli, Serkan Yıldırım, Erdal Ege, Volkan Burak Taban

Abstract

Objective: The aim of this study was to investigate postoperative left ventricular changes [left ventricular mass (LVM), left ventricular mass index (LVMI), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), patient–prosthesis mismatch (PPM), pulmonary artery pressure (PAP), gradients, and ejection fraction (EF)] according to the valve type used in patients undergoing aortic valve replacement (AVR) due to isolated aortic stenosis.

Methods: A total of 199 patients with isolated AVR due to aortic stenosis between 2010 and 2020 was retrospectively investigated. Four groups were identified according to the valve type used (mechanical, bovine pericardium, porcine and sutureless). Pre-operative and first year postoperative transthoracic echocardiography findings for the patients were compared.

Results: Mean age was 64.4 ± 13.0 years, while the gender distribution was 41.7% women and 58.3% men. Of the valves used in patients, 39.2% were mechanical, 18.1% were porcine, 8.5% were bovine pericardial and 34.2% were sutureless valves. Analysis independent of the valve groups observed LVEDD, LVESD, maximum gradient, mean gradient, PAP, LVM and LVMI values reduced significantly postoperatively ($p < 0.001$). EF was observed to increase by 2.1% ($p = 0.008$). Comparisons of the four valve groups revealed that LVEDD, LVESD, maximum gradient, mean gradient, LVM and LVMI significantly decreased in all groups. EF significantly increased only in the sutureless valve group ($p = 0.006$). Analysis of PPM groups showed that LVESD, maximum gradient, mean gradient, PAP, LVM and LVMI were significantly reduced in all groups. In the normal PPM group, there was an improvement in EF, which was significantly different to the other groups ($p = 0.001$), while in the severe PPM group, EF appeared to be reduced ($p = 0.19$).

Keywords: left ventricular mass, left ventricular mass index, aortic stenosis, aortic valve replacement, patient–prosthesis mismatch

Submitted 9/12/22, accepted 1/3/23

Cardiovasc J Afr 2023; online publication www.cvja.co.za

DOI: 10.5830/CVJA-2023-012

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In developed countries, aortic stenosis is the valve disease requiring most frequent intervention.[1] The prevalence of aortic stenosis in patients between 60 and 74 years of age is reported to be 2.8%, and 13.1% in people aged 75 years and older.[2]

Left ventricular hypertrophy linked to aortic stenosis causes the development of symptoms and side effects characterising the later stages of this disease. Even successful aortic valve replacement (AVR) after severe left ventricular hypertrophy is associated with a worse left ventricular function, and higher early and late mortality rates.[3,4] Regression of left ventricular mass (LVM) reaches a plateau in the first year after AVR.[5] Inadequate postoperative regression of left ventricular hypertrophy may be an indication of irreversible remodelling and hence a worse prognosis.[6,7] Regression of left ventricular hypertrophy was shown to be associated with improved long-term survival.[8,9]

Some factors involved in regression of left ventricular hypertrophy have been reported. Among these are age, gender, hypertension, diabetes, coronary artery disease, atrial fibrillation (AF), prosthetic valve type used and degenerative myocardial changes.[8] Additionally, the effect of patient–prosthesis mismatch (PPM) on left ventricular remodelling is controversial.

In this study, the aim was to investigate postoperative left ventricular changes [LVM, left ventricular mass index (LVMI), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), PPM, pulmonary artery pressure (PAP), gradient, and ejection fraction (EF)] according to the valve type used in patients undergoing AVR due to isolated aortic stenosis.

Methods

A total of 290 patients with AVR due to isolated aortic stenosis from January 2010 to January 2020 in our clinic was retrospectively investigated. Patients with a previous history of cardiac operation with additional procedures (coronary artery bypass graft, ascending aorta replacement and aortic root expansion), pregnant and/or breastfeeding, under 18 years of age, with emergency procedures performed, and those with a primary diagnosis of aortic regurgitation were excluded from the study. The study included 199 adult patients with a main diagnosis of isolated aortic stenosis. Detailed characteristics of the patients were obtained from file records and the hospital software system.

Permission was granted by the local ethics committee for the study protocol (2022/3652) and every patient provided written informed consent. The study was completed according to the principles of the Declaration of Helsinki.

Four groups were identified according to the valve type used in the operation. These were mechanical valve, bovine bioprosthetic (pericardial) valve, porcine bioprosthetic valve and sutureless valve. The pre-operative transthoracic echocardiography findings of patients (LVM, LVMI, LVEDD, LVESD, PPM, PAP, EF and gradient) were compared with the one-year (from 10 to 15 months) postoperative transthoracic echocardiography results.

The LVM and LVMI values of patients were calculated with the commonly used formula based on echocardiographic parameters developed by Devereux and Reichek. The body surface area (BSA) of patients was calculated by measuring their height and weight. LVM was calculated with the following formula:

$$\text{LVM (g)} = 0.8 \times [1.04\ (\text{LVEDD} + \text{PWt} + \text{IVSt})^3 - (\text{LVEDD})^3] + 0.6$$

where IVSt is interventricular septum thickness, PWt is posterior wall thickness, 1.04 is the myocardial specific weight and 0.8 is the correction factor.

Table 1. Demographic data and related descriptive statistics

Patient characteristics	*Frequency (*n*)*	*Percentage (%)*
Age group, years		
19–49	23	11.6
50–65	65	32.7
> 65	111	55.7
Gender		
Women	83	41.7
Men	116	58.3
Demographic data		
Diabetes mellitus	50	25.1
Hypertension	163	81.9
Chronic obstructive pulmonary disease	55	27.6
Peripheral vascular disease	12	6.0
Coronary artery disease	64	32.1
Atrial fibrillation	36	18.0
Cerebrovascular disease	9	4.5
Cardiac pacing device	2	1.0
Pulmonary embolism	1	0.5
Epilepsy	2	1.0
Congenital hearing loss	1	0.5
Bipolar disorder	1	0.5
History of malignancy	3	1.5

LVMI was calculated with the following formula:

$$\text{LVMI (g/m}^2) = \text{LVM/BSA}$$

Patients were classified in terms of PPM as severe, moderate and normal according to the indexed effective orifice area (IEOA) (severe: IEOA < 0.65 cm²/m², moderate: 0.65 ≤ IEOA ≤ 0.85 cm²/m², normal: IEOA > 0.85 cm²/m²). The predicted effective orifice area (EOA) of the implanted prosthetic valve was calculated using the previously published EOA measurements for each valve type and size.[10-12] IEOA was calculated with the following formula:

$$\text{IEOA (cm}^2/\text{m}^2) = \text{EOA/BSA}$$

Statistical analysis

We used the SPSS 21.0 (IBM Inc, Chicago, IL, USA) program for statistical analysis. Numerical parameters are given as mean ± standard deviation, while categorical variables are given as frequency and percentage. Fit to normal distribution was examined with the Kolmogorov–Smirnov test. Analysis of homogeneity of numerical parameters was done with the Levene test. Comparison of independent groups was done with the independent samples *t*-test or one-way analysis of variance (ANOVA). Comparison of pre-operative–postoperative dependent parameters was done with the paired *t*-test. Binary logistic regression analysis was used for identification of predictive factors. Model regression fit was tested with the Box–Tidwell test. The fit of binary logistic regression models was confirmed with the Hosmer and Hemeshow test. Analysis of categorical groups was done with the chi-squared test. Suitable parameters were analysed with receiver operating characteristic (ROC) curves and diagnostic data were determined. For the whole study, the type-I error rate was 5% and $p < 0.05$ was accepted as significant.

Results

The mean age of the 199 patients included in the study was 64.4 ± 13.0 years, and the gender distribution was 41.7% women (n = 83) and 58.3% men (n = 116). Mean body mass index was 28.8 ± 5.4 kg/m² and mean BSA was 1.84 ± 0.19 m². Mean cardiopulmonary bypass duration was 85.21 ± 27.53 minutes with a mean cross-clamp duration of 59.12 ± 22.14 minutes. Demographic data are given in Table 1.

According to the New York Heart Association (NYHA) heart failure classification, the class I patient rate was 9.5% (n = 19), class II was 74.9% (n = 149), class III was 15.6% (n = 31) and class IV was 0%.

When the types of valves used were investigated, 78 patients had mechanical valves (39.2%), 36 had porcine valves (18.1%), 17 had bovine pericardial valves (8.5%) and 68 had sutureless valves (34.2%). The use of biological valves was higher in the group over 64 years (76.3%; n = 98), while selection of mechanic valves was higher in the 50–65-year age group (76.4%; n = 42). The mean valve dimension was 22.89 ± 2.41 mm. The distribution of valve brands used is given in Fig. 1.

According to the four valve groups, echocardiographic findings for surviving patients in the first year postoperatively

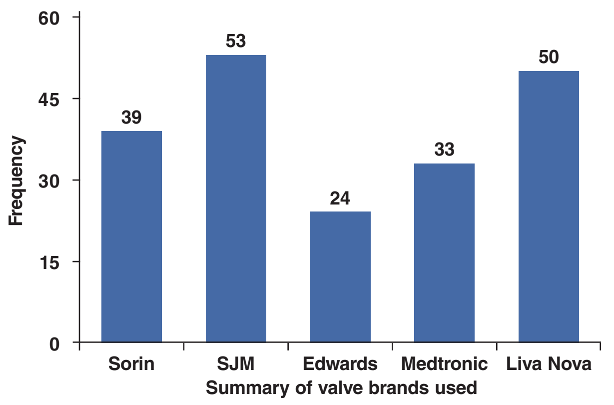

Fig. 1. Subgroups and statistical distribution of valve brands used.

Table 2. Statistical analysis of first year postoperative echocardiographic data by valve type

Echocardio-graphic data	*Porcine valve (mean ± SD)*	*Bovine pericardial valve (mean ± SD)*	*Sutureless valve (mean ± SD)*	*Mechanical valve (mean ± SD)*	p-*value*
EF, %	54.85 ± 6.79	55.67 ± 4.95	56.20 ± 6.51	56.40 ± 5.95	0.39
LVEDD, cm	4.53 ± 0.43	4.57 ± 0.57	4.46 ± 0.45	4.59 ± 0.57	0.89
LVESD, cm	2.73 ± 0.42	2.84 ± 0.67	2.66 ± 0.54	2.82 ± 0.59	0.29
Maximum gradient, mmHg	27.79 ± 11.60	23.73 ± 8.77	19.87 ± 7.67	26.85 ±12.47	0.001
Mean gradient, mmHg	15.67 ± 7.89	13.07 ± 5.12	11.04 ± 4.79	14.40 ± 7.48	0.007
PAP, mmHg	34.45 ± 7.55	35.20 ± 7.99	34.20 ± 9.166	30.63 ± 5.54	0.013
LVM, g	180.27 ± 31.70	200.60 ± 50.92	178.42 ± 33.88	189.38 ± 53.24	0.54
LVMI, g/m²	97.12 ± 20.01	104.40 ± 26.44	101.14 ± 17.81	100.38 ± 25.36	0.51

EF: ejection fraction; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; PAP: pulmonary artery pressure; LVM: left ventricular mass; LVMI: left ventricular mass index.

(n = 176) showed significant statistical changes in maximum gradient, mean gradient and PAP. The mean maximum gradient value was highest in the porcine valve group (27.79 ± 11.60 mmHg) and lowest in the sutureless valve group (19.87 ± 7.67 mmHg) (p = 0.001). The mean gradient value was highest in the porcine valve group (15.67 ± 7.89 mmHg) and lowest in the sutureless valve group (11.04 ± 4.79 mmHg) (p = 0.007). The postoperative mean PAP values were observed to be highest in the bovine pericardial valve group (35.20 ± 7.99 mmHg) and lowest in the mechanical valve group (30.63 ± 5.54 mmHg) (p = 0.013) (Table 2).

The pre-operative and one-year postoperative echocardiography findings for patients were compared in general without dividing into valve groups. From this investigation, LVEDD, LVESD, maximum gradient, mean gradient, PAP, LVM and LVMI values were statistically significantly reduced in the postoperative period (p < 0.001). The EF value was statistically significantly increased in the postoperative period (p = 0.008) (Table 3). The amount of variation between postoperative and pre-operative values was analysed and the direction of change, percentage change and standard deviation values are given in Table 4.

The pre- and postoperative echocardiographic findings were separately investigated in the four valve groups. Mean values for LVEDD, LVESD, maximum gradient, mean gradient, LVM and LVMI showed statistically significant reductions in the postoperative period in all groups. For EF, in spite of the increase in all groups, this increase was found to be significant only in the sutureless valve group (p = 0.006) (Table 5).

The difference between pre- and postoperative echocardiographic findings were analysed according to the PPM classification of patients (IEOA severe, moderate, normal). The distribution of severe, moderate and normal PPM in the four valve groups was 20, 73.4 and 6.6% in the bovine pericardial valve group (n = 15); 9, 73 and 18% in the porcine valve group (n = 33); 5.4, 36.4 and 58.2% in the mechanical valve group (n = 74); and 0, 29.7 and 70.3% in the sutureless valve group (n = 54).

In all groups, a decrease was observed for LVEDD, LVESD, maximum gradient, mean gradient, LVM and LVMI. Only LVEDD did not show a significant change in the severe PPM

Table 3. General comparison of pre-operative and first year postoperative echocardiographic findings of the patients

Parameters	*Pre-operative echocardiography*	*Postoperative echocardiography*	p-*value*
Ascending aortic diameter, cm	4.04 ± 0.30	4.22 ± 0.30	0.27
EF, %	54.87 ± 7.84	55.98 ± 6.20	0.008
LVEDD, cm	4.77 ± 0.74	4.54 ± 0.51	< 0.001
LVESD, cm	3.00 ± 0.70	2.76 ± 0.55	< 0.001
Maximum gradient, mmHg	84.64 ± 19.41	24.63 ± 11.17	< 0.001
Mean gradient, mmHg	52.46 ± 13.83	13.50 ± 6.85	< 0.001
PAP, mmHg	36.16 ± 10.46	32.82 ± 7.57	< 0.001
LVM, g	228.76 ± 66.61	185.29 ± 44.42	< 0.001
LVMI, g/m²	124.15 ± 34.46	100.35 ± 22.31	< 0.001

EF: ejection fraction; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; PAP: pulmonary artery pressure; LVM: left ventricular mass; LVMI: left ventricular mass index.

Table 4. Analysis of the amount of postoperative change, percentage of change and direction of change in echocardiographic parameters compared to pre-operative data

Parameters	*Range of change*	*Direction of change*	*Percentage change (%)*	*Amount of change (mean ± SD)*
Δ EF, %	Pre-operative Postoperative	↑	2.93 ± 11.46	1.01 ± 4.79
Δ LVEDD, cm	Pre-operative Postoperative	↓	24.03 ± 383.83	0.23 ± 0.65
Δ LVESD, cm	Pre-operative Postoperative	↓	6.05 ± 18.01	0.24 ± 0.55
Δ LVM, g	Pre-operative Postoperative	↓	16.21 ± 18.64	44.56 ± 52.47
Δ LVMI, g/m²	Pre-operative Postoperative	↓	16.25 ± 18.64	24.17 ± 27.96
Δ Maximum gradient, mmHg	Pre-operative Postoperative	↓	69.40 ± 15.66	60.01 ± 27.96
Δ Mean gradient, mmHg	Pre-operative Postoperative	↓	72.99 ± 15.34	39.62 ± 15.55
Δ Ascending aorta diameter, cm	Pre-operative Postoperative	↑	2.85 ± 7.02	0.10 ± 0.27
Δ PAP, mmHg	Pre-operative Postoperative	↓	3.69 ± 23.75	2.58 ± 9.07

Δ: difference between postoperative and pre-operative values; ↑: increase; ↓: decrease; EF: ejection fraction; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; PAP: pulmonary artery pressure; LVM: left ventricular mass; LVMI: left ventricular mass index.

Table 5. Comparison of pre-operative and first year postoperative echocardiographic findings according to valve subgroups of the patients

Parameters	*Valve type*	*Pre-operative echocardiography (mean ± SD)*	*Postoperative echocardiography (mean ± SD)*	p-*value*
Ascending aortic diameter, cm	Porcine	4.10 ± 0.26	4.18 ± 0.22	0.46
	Bovine pericardial	4.03 ± 0.29	4.23 ± 0.05	0.28
	Sutureless	3.97 ± 0.34	4.25 ± 0.44	0.09
	Mechanical	4.08 ± 0.29	4.21 ± 0.26	0.54
EF, %	Biyolojik porcine	54.31 ± 8.12	54.85 ± 6.79	0.87
	Bovine pericardial	54.41 ± 5.55	55.67 ± 4.95	0.33
	Sutureless	54.19 ± 8.17	56.20 ± 6.5	0.006
	Mechanical	55.83 ± 7.87	56.40 ± 5.95	0.20
LVEDD, cm	Biyolojik porcine	4.98 ± 0.53	4.53 ± 0.43	< 0.001
	Bovine pericardial	4.66 ± 0.51	4.57 ± 0.57	0.04
	Sutureless	4.64 ± 0.55	4.46 ± 0.45	0.003
	Mechanical	4.82 ± 0.96	4.59 ± 0.57	< 0.001
LVESD, cm	Biyolojik porcine	3.16 ± 0.71	2.73 ± 0.42	0.001
	Bovine pericardial	2.96 ± 0.69	2.84 ± 0.67	0.03
	Sutureless	2.90 ± 0.62	2.66 ± 0.54	< 0.001
	Mechanical	3.03 ± 0.76	2.82 ± 0.59	0.02
Maximum gradient, mmHg	Biyolojik porcine	81.76 ± 18.47	27.79 ± 11.60	< 0.001
	Bovine pericardial	87.07 ± 20.38	23.73 ± 8.77	< 0.001
	Sutureless	83.59 ± 18.38	19.87 ± 7.67	< 0.001
	Mechanical	86.19 ± 20.48	26.85 ± 12.47	< 0.001
Mean gradient, mmHg	Biyolojik porcine	51.44 ± 13.20	15.67 ± 7.89	< 0.001
	Bovine pericardial	56.71 ± 15.35	13.07 ± 5.12	0.001
	Sutureless	51.12 ± 12.21	11.04 ± 4.79	< 0.001
	Mechanical	53.18 ± 15.09	14.40 ± 7.48	< 0.001
PAP, mmHg	Biyolojik porcine	35.86 ± 10.49	34.45 ± 7.55	0.55
	Bovine pericardial	38.18 ± 11.30	35.20 ± 7.99	0.37
	Sutureless	38.26 ± 12.22	34.20 ± 9.16	0.02
	Mechanical	34.01 ± 8.08	30.63 ± 5.54	< 0.001
LVM, g	Biyolojik porcine	246.25 ± 62.89	180.27 ± 31.70	< 0.001
	Bovine pericardial	221.53 ± 64.26	200.60 ± 50.92	0.03
	Sutureless	212.35 ± 46.55	178.42 ± 33.88	< 0.001
	Mechanical	236.58 ± 80.09	189.38 ± 53.24	< 0.001
LVMI, g/m^2	Biyolojik porcine	132.11 ± 36.80	97.12 ± 20.01	< 0.001
	Bovine pericardial	115.06 ± 35.77	104.40 ± 26.44	0.02
	Sutureless	120.99 ± 26.19	101.14 ± 17.81	< 0.001
	Mechanical	125.21 ± 38.96	100.38 ± 25.36	< 0.001

EF: ejection fraction; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; PAP: pulmonary artery pressure; LVM: left ventricular mass; LVMI: left ventricular mass index.

group (p = 0.23), while statistically significant decreases were observed in the other groups. PAP did not show significant decrease in the severe PPM group (p = 0.20), while there were significant decreases in the moderate PPM (p = 0.02) and normal PPM groups (p = 0.001). EF revealed a significant increase only in the normal PPM group (p = 0,001), while a decrease was seen in the severe PPM group (p = 0.19) (Table 6).

One-year postoperative echocardiographic aortic valve assessment revealed minimum valvular aortic regurgitation (AR) in 95.4% of patients (n = 168), with first-degree valvular AR in 2.8% of patients (n = 5) and second-degree paravalvular AR in 1.7% of patients (n = 3). Postoperative assessment identified newly developing AF in 21.6% of patients (n = 43), cerebrovascular events in 6% of patients (n = 12), full atrioventricular block in 3.5% of patients (n = 7) and end-stage renal failure in 1.5% of patients (n = 3). At the end of the first year, 11.5% of patients had died (n = 23) and 88.5% of patients survived (n = 176).

Table 6. Comparison of pre-operative and first year postoperative echocardiographic findings according to PPM (IEOA) of the patients

Parameters	*IEOA*	*Pre-operative echocardiography (Mean ± SD)*	*Postoperative echocardiography (Mean ± SD)*	p-*value*
EF, %	Severe	58.57 ± 3.05	57.00 ± 4.83	0.19
	Moderate	55.72 ± 7.07	56.20 ± 5.94	0.34
	Normal	53.68 ± 8.64	55.67 ± 6.58	0.001
LVEDD, cm	Severe	4.55 ± 0.36	4.28 ± 0.38	0.23
	Moderate	4.75 ± 0.57	4.51 ± 4.41	< 0.001
	Normal	4.82 ± 0.88	4.59 ± 0.57	< 0.001
LVESD, cm	Severe	2.74 ± 0.39	2.48 ± 0.30	0.04
	Moderate	2.97 ± 0.67	2.74 ± 0.53	< 0.001
	Normal	3.06 ± 0.75	2.80 ± 0.59	< 0.001
Maximum gradient, mmHg	Severe	86.60 ± 25.64	30.80 ± 10.05	< 0.001
	Moderate	83.82 ± 17.91	27.62 ± 12.58	< 0.001
	Normal	85.15 ± 20.10	21.33 ± 8.79	< 0.001
Mean gradient, mmHg	Severe	56.64 ± 19.01	17.30 ± 6.01	0.005
	Moderate	51.76 ± 11.82	15.41 ± 8.14	< 0.001
	Normal	52.46 ± 14.57	11.39 ± 4.77	< 0.001
PAP, mmHg	Severe	36.07 ± 12.79	33.50 ± 8.33	0.20
	Moderate	36.12 ± 10.05	34.29 ± 8.75	0.02
	Normal	36.20 ± 10.56	31.45 ± 6.04	< 0.001
LVM, g	Severe	204.57 ± 44.79	168.00 ± 41.05	0.01
	Moderate	221.69 ± 55.06	188.064 ± 40.68	< 0.001
	Normal	237.84 ± 76.01	184.80 ± 47.79	< 0.001
LVMI, g/m^2	Severe	105.29 ± 21.83	89.00 ± 18.49	0.01
	Moderate	118.30 ± 28.39	99.67 ± 19.65	< 0.001
	Normal	131.49 ± 38.48	102.213 ± 24.59	< 0.001

IEOA: indexed effective orifice area; EF: ejection fraction; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; PAP: pulmonary artery pressure; LVM: left ventricular mass; LVMI: left ventricular mass index.
Severe IEOA < 0.65; moderate IEOA 0.65–0.85; normal IEOA > 0.85.

Discussion

Aortic stenosis causes chronic pressure loading and the left ventricle responds with hypertrophy to normalise the systolic wall stress.[13] With the return to normal of systolic pressure after AVR, the left ventricular end-systolic and end-diastolic volume indexes fall. As a result, reversal of left ventricular hypertrophy and improvement in functional capacity is expected. A study by Koyama *et al.*[14] identified that 30 patients with mechanical AVR due to aortic stenosis had significant decrease in LVM at the end of one year (from 245.1 ± 84.3 to 173.4 ± 62.6 g). Suri *et al.*[15] studied AVR patients with porcine and bovine pericardial valves and reported that in spite of significant LVM decreases at the end of a year, there was no significant difference identified between the two groups.

Rubens *et al.*[16] studied 258 patients with left ventricular hypertrophy undergoing AVR with Trifecta (St Jude Medical, St Paul, Minnesota) or Perimount Magna Ease (Edwards Life Sciences, Irvine, California) bovine pericardial valves. They stated that Trifecta was associated with a significant degree of LVM decrease and improved medium-term clinical outcomes compared to Perimount Magna Ease valves.

A study by Concistrè *et al.*[17] showed significant LVM decrease in patients using Perceval S (Sorin Group, Saluggia, Italy) and 3f Enable (Medtronic, ATS Medical, Minneapolis, MN USA) sutureless valves due to aortic stenosis; however, no significant difference was found between the two valve groups. Santarpino *et al.*[18] used Perceval S for sutureless AVR in 78 patients with aortic stenosis and observed significant decrease in LVMI (from 148.4 ±

46 to 119.7 ± 38.5 g/m²) and mean transaortic pressure difference (from 49.5 ± 15.8 to 8.3 ± 4.4 mmHg) during one-year follow up.

In our study, general analysis without differentiating the valve subgroups revealed mean LVM decreased from 228.76 ± 66.61 to 185.29 ± 44.42 g at the end of one year ($p < 0.001$), while mean LVMI decreased from 124.15 ± 34.46 to 100.35 ± 22.31 g/m² ($p < 0.001$). The mean transaortic pressure difference reduced from 52.46 ± 13.83 to 13.50 ± 6.85 mmHg ($p < 0.001$). Additionally, at the end of the first year, there was a significant increase in EF ($p = 0.008$). In the four valve groups (bovine pericardial, porcine, sutureless and mechanical valves), all groups were observed to have significant decrease of mean LVEDD, LVESD, maximum gradient, mean gradient, LVM and LVMI in the postoperative period.

Analysis of the four valve groups showed the bovine pericardial valve group had less LVM (bovine pericardial 10.1%, porcine 24.5%, sutureless 13.7% and mechanical 16%) and LVMI (bovine pericardial 10.5%, porcine 24.3%, sutureless 13.8% and mechanical 16%) percentage decrease compared to the other valve groups. When patients in the bovine pericardial valve group were examined in detail, 20% of patients were identified to have severe PPM. In the other valve groups the severe PPM rates were 9% for porcine, 5.4% for mechanical valves and 0% for sutureless valves. We believe LVM and LVMI were less decreased in the bovine pericardial valve group because of the higher number of severe PPM cases in this group. The lack of severe PPM cases in the sutureless group may be explained by this valve having better EOA.[10-12] Additionally, the observation of lower mean maximum gradient ($p = 0.001$) and mean gradient ($p = 0.007$) values in the sutureless valve group compared to the other valve groups supports this view.

In patients undergoing AVR, PPM may be observed when the prosthetic valve implanted is small compared to the body size of the patient. Dayan *et al*. showed the prevalence of PPM at a moderate level was from 20 to 70%, while the prevalence of severe PPM varied from two to 20%.[19] PPM was shown to predict a negative outcome.[20-24] The effect of PPM on remodelling of left ventricular hypertrophy is debatable. A range of studies showed that PPM was associated with remodelling after AVR and transcatheter aortic valve implantation (TAVI),[25] while some studies found it had a limited effect on clinical outcomes.[26,27] The presence of PPM was not found to have a significant effect on postoperative EF changes.[19]

When the valve groups in our study were investigated in terms of PPM, mean LVEDD, LVESD, maximum gradient, mean gradient, PAP, LVM and LVMI appeared to decrease in all PPM groups. For EF, while significant improvement was observed in the normal PPM group, decrease was identified in the severe PPM group (from 58.5 to 57.0%) ($p = 0.19$) (Table 6).

Left ventricular systolic dysfunction may be due to increasing load in the presence of normal myocardial contractility and absence of significant myocardial dysfunction, and it is expected that systolic function will improve after removal of the output obstruction. An article published by Kim *et al.*[25] reported 4% improvement rate for EF during the one-year follow up for patients with AVR due to aortic stenosis and an EF of 50% and above.

In our study, without differentiating the subgroups, general assessment identified a mean 2.1% rate of significant improvement in EF. When analysis was performed according to the valve subgroups, all groups were found to have an increase in EF, while this increase was only statistically significant in the sutureless valve group ($p = 0.006$). This situation may be due to the sutureless valves having better EOA.[10-12] It is necessary to take a separate view for the severe PPM group when assessing EF. Unlike in the other groups, the decrease in EF in the severe PPM group makes the benefit of surgery controversial for patients. Therefore, in spite of appropriate selection of valves for patients in the severe PPM group, aortic root expansion should be considered if IEAO is < 0.65.

There is not much data in the literature related to PAP changes in patients undergoing AVR due to aortic stenosis. Analysis of the four valve groups in our study observed a postoperative fall in PAP in all groups. However, this reduction was only significant in the mechanical ($p < 0.001$) and sutureless ($p = 0.02$) valve groups. We believe this result is associated with the reduction in left ventricular volume load after AVR and linked reduction in pulmonary load. PAP changes affect the mitral and tricuspid valves and pulmonary bed reserve apart from the aortic valve. Therefore, there is a need for prospective randomised studies to be able to determine the effects of different valve types.

It was observed that a large diameter increase in the ascending aorta in the first postoperative year was found especially in patients over 65 years of age. We believe that this significant increase may be related to senile degeneration of the aortic wall with increasing age.

The limitations of our study are that it was retrospective, echocardiography assessment was performed only in the first year, and the number of patients in each valve group was different and limited.

Conclusion

In our study, analysis comparing four valve groups revealed significant decreases in LVEDD, LVESD, maximum gradient, mean gradient, LVM and LVMI in all groups at the end of the first year. EF was observed to significantly improve only in the sutureless valve group. Additionally, the sutureless valve group showed significant reductions in maximum gradient and mean gradient values compared to the other valve groups. PPM investigation revealed significant improvement in EF in the normal PPM group compared to the severe and moderate PPM groups, while insignificant decrease was observed in the severe PPM group. We believe that aortic root enlargement should be performed in patients in the severe PPM group if IEOA is < 0.65, despite appropriate valve selection.

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