Echocardiography Evaluation of Homograft and Prosthetic Valves in the Aortic Position

HOMOGREFT VE MEKANİK AORTİK PROTEZ KAPAKLARIN EKOKARDİYOGRAFİK DEĞERLENDİRMESİ

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Summary

This study was designed to examine the effects of prosthetic and homograft aortic valves on ventricular hemodynamics and structure, in a comparative manner.

The hemodynamic evaluations were performed in 32 patients, who had undergone aortic valve replacement with either a homograft (n=16) or a prosthetic valve (19-23mm, n=16). Pressure gradient (PG), aortic valve area, diameters of left atrium, posterior wall (PW), interventricular septum (IVS), ejection fraction (EF), left ventricular mass (LVM) and mass index (LVMl) were evaluated by using M-mode, two-dimensional and Doppler echocardiography examinations.

Although LVM and LVMI measurements of both groups had showed significant reductions postoperatively (p<0.001) there was a significant difference favoring homograft group in comparison of two groups (p<0.05). IVS and PW diameters of homograft group reduced significantly at postoperative period (p<0.05) and the difference between two groups was also significant (p<0.01). The improvement in EF of homograft group was significant (p<0.05).

The more favorable results of LVM, LVMI, PG, IVS, and PW thicbiess measurements in homograft group suggest that homograft valves in aortic position have better hemodynamic effects on ventricular performances than the prosthetic ones.

**Key Words: Echocardiography, Homograft,
Aortic valve replacement**

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Özet

Bu çalışma protez ve homogreft aortik kapakların ventrikül hemodinamisi ve yapısı üzerine olan etkilerini karşılaştırmalı bir şekilde değerlendirmek amacıyla yapılmıştır.

Hemodinamik değerlendirmeler eşit sayıda hasta içeren homogreft ya da mekanik aortik kapak replasmam (19-23 mm) uygulanmış iki gruptan oluşan 32 hasta üzerinde yapılmıştır. M-mode, iki boyutlu ve Doppler ekokardiyografi kullanılarak basınç gradiyenti, aortik kapak alanı, sol atrium çapı, arka duvar kalınlığı, ventriküller arası septum kalınlığı, ejeksiyon fraksiyonu, sol ventrikül kitlesi ve kitle indeksleri hesaplanmıştır.

Her iki grubun sol ventrikül kitle ve kitle indeksleri postoperatif dönemde anlamlı derecede azaldıysa da (p<0.001), iki grubun karşılaştırılmasında bu azalmanın homogreft grubunda daha anlamlı olduğu bulunmuştur (p<0.05). Homogreft grubunun ventriküller arası septum ve arka duvar çaplarında dapostoperatif dönemde azalma olmuş (p<0.05) ve bu azalma mekanik protez grubuna kıyasla anlamlı bulunmuştur (p<0.01). Ejeksiyon fraksiyonunduk! gelişme homogreft grubunda daha beliıgindir (p<0.05).

Homogreft grubunun sol ventrikül kitle ve kitle indeksi, ventriküller arası septum veposterior duvar kalınlıkları ile ejeksiyon fraksiyonu ölçümlerindeki üstün performansı, aort kapak replasmanında homogreft kapakların mekanik protezlere göre daha iyi hemodinamik etkilere sahip olduklarını göstermektedir.

Anahtar Kelimeler: Ekokardiyografı, Homogreft,
Aortik kapak replasmam

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The degree of improvement in left ventricular (LV) structure and function after aortic valve replacement (AVR) is closely related to stage and type of secondary cardiomyopathy at the operation, intraoperative myocardial damage, preoperative etiology of valvular insufficiency or stenosis, and type of valve prosthesis which is always a debated matter.

If the aortic stenosis is the dominant lesion, the functional response of LV might be faster than the morphologic changes of it. Left ventricular end diastolic (LVEDV) and end systolic volume

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(LVESV) levels fall and ejection fraction (EF) increases significantly within 6 months after the AVR (1). The LV systolic function indices return to normal or supranormal levels in most of the patients. There are similar but somewhat less improvements of EF, LVEDV, and LVESV indices after the AVR, in patients with dominant aortic regurgitation. However, 60% of such patients with preoperative dysfunction remain as having dysfunction at postoperative term.

The pressure gradient between the LV and aorta was detected as minimal after the homograft AVR and more considerable after the mechanic or biologic prosthesis valve replacement (2). Type of prosthesis, the compatibility of native annulus with prosthesis size, cardiac output in rest or exercise, the evolving process around or within the prosthesis, all effect the degree of pressure gradient. Almost all mechanic and biologic prostheses smaller than 23 mm in size are obstructive when the cardiac output (CO) increases, whereas ones greater than 21 mm can provide adequate performance in most of adult patients. However, some 19 mm in size prostheses can be used safely in patients having smaller BSA, due to their relatively low CO levels (3).

The selection of a prosthesis with favorable hemodynamic features is an important matter for cardiovascular surgeons. Especially, the replacement of small prosthetic valves in aortic position has a considerable risk of transaortic valvular pressure gradient (4). The use of homographs with previously proved better clinical results, and without any complication of thromboembolism, hemorrhage, and sudden death, has gained a recent revival of interest by the advent of cryopreservation technique.

The purpose of this study was to compare the hemodynamic effects of homograft and various prosthetic valves, irrespective for its types, in somewhat small aortic annuli. Different prosthetic valve types were studied rather than one, to conclude a common concept regarding some current prosthetic valves.

Materials and Methods

Thirty-two patients who had undergone aortic valve replacement between 1991 and 1998 were hemodynamically evaluated. Patients were allocated into two groups who received either a homograft (n=16) or prosthetic (n=16) valve. In selection of patients, prosthesis sizes of prosthetic group matched and comparable to those of homograft group were taken into account. The patients with preoperatively diagnosed renal failure, diabetes, hypertension, evidence of ongoing ischemia (angina and ST changes), taking antiarrhythmic therapy, undergoing reoperation or emergent operation were excluded. There was no concomitant surgery such as coronary artery bypass (CABG) or another valve replacement. The preoperative aortic lesions of homograft group were aortic regurgitation in 11(68.8%), and combined aortic stenosis and regurgitation in 5 (31.3%) patients, whereas the preoperative lesions of prosthetic group were isolated aortic regurgitation in 6 (37.5%), and combined aortic stenosis and regurgitation in 10 (62.5%) patients. There were 7 (43.8%) women and 9 (56.3%) men in each group. The following homograft valve sizes were replaced: 19 mm (n=2), 21 mm (n=10), 23 mm (n=4), being the mean valve size as 21±0.6 mm. The sizes and types of replaced prosthetic valves were: 19 mm St. Jude Medical (SJM) Hemodynamic Plus (HP) (n=2), 21 mm SJM-HP (n=2), 21 mm SJM (n=5), 21 mm Sorin Biomedica (n=2), 23 mm SJM (n=2), 23 mm Sorin Biomedica (n=2), 23 mm Dura Medics(n=l) and the mean size was 21±1.1mm.

There were 1 and 2 patients in atrial fibrillation in homograft and prosthetic groups, respectively at preoperative period, however, all patients returned to normal sinus rhythm postoperatively. There was not any significant difference between two groups regarding preoperative lesion, age, sex, and body surface area (BSA). The operative and demographic data of patients are shown in Table 1.

The work was approved by ethic committee of this hospital and informed consents were obtained from all patients. All operations were performed through median sternotomy incision. The membrane oxygenator was primed with 2 L of lactated Ringer's solution. CPB was established via standard aortic and single venous cannulation. During bypass the hematocrit was maintained between 20% and 25%, nonpulsatile pump flow between 2.0 and 2.5 L/min/m^2 and mean arterial pressures between 50 and 65 mmHg. After the aortic cross-

Table 1. Basic operative and demografic data of the patients. (AR: aortic regurgitation, AS: aortic stenosis, **cp:** standard deviation, BSA: body surface area, CPB: cardiopulmonary bypass time, X Clamp: cross clamping time.)

	Homograft		Prosthetic		
	n	%	n	%	p
Sex					*
Female	7	43.8	7	43.8	
Male	9	56.3	9	56.3	NS
Disease					
AR	11	68.8	6	37.5	
AR+AS	5	31.3	10	62.5	NS

	Homograft Mean±SD	Prosthetic Mean±SD	p
BSA (m^2)	1.73 ±0.15	1.81 ±0.12	NS
Age (year)	39.34 ± 13.19	45.09 ± 10.21	NS
CPB (min)	170.94±25.38	86.94 ± 15.08	<0.01
X Clamp (min)	142.21 ± 19.41	69.38 ± 12.15	<0.01
Hospitalization(day)	11.25 ±5.09	6.52± 4.34	NS
Follow up (month)	30.07±26.37	24.10±15.84	NS

clamping, all patients received intermittent, moderately hypothermic blood cardioplegia. Topical hypothermia was also used in all operations. Body temperature was maintained between 28 and 30°C during CPB. Any cell-saver application was not needed along the course of study.

Homograft valves were obtained with informed consent from the families of donors and prepared, thawed and preserved according to protocol of Royal Brompton Hospital. The homograft valve replacement was performed by subcoronary implantation technique in all patients but one for whom mini-root replacement was applied because of endocarditis. Standard surgical technique was used for all prosthetic aortic valve replacements and no patient had annular enlargement. The mean cardiopulmonary bypass (CPB) and aortic cross clamping (X-clamp) times of homograft group were significantly longer than those of prosthetic group. The mean postoperative hospitalization periods of both groups were similar. Although the interval between operation and follow -up echocardiographic evaluation of homograft group (30.07±26.37 months) was longer than that of prosthetic group (24.10±15.84 months) the difference was not statistically significant.

Both preoperative and follow-up transthoracic echocardiographic evaluations were performed using a Hewlett-Packard Sonos ultrasound imaging system (Hewlett-Packard Company, Palo Alto, CA) with a 2/2.75 MHZ phased array transducer. All measurements were performed as M-mode and 2-D, and Doppler echocardiography based on standard calculations established by American Society of Echocardiography (5, 6).

Aortic valve area (AVA=EOA) was calculated by the continuity equation as Gorlin formula of echocardiography, by the simplified peak velocity method as $AVA=CSA(PkV_{LVOT}/PkV_{JET})$ (5). It is based on equality of in and out flows (F1=F2).

The modified Bernoulli equation was used to calculate the transaortic pressure gradients: $AP=4(V_2)^2$ (5, 6).

Left ventricular end diastolic (LVEDd) and end systolic diameter (LVEDs), left atrium diameter (LAD), interventricular septum thickness (IVS), posterior wall thickness (PW), aortic root diameter, ejection fraction (EF) measurements were performed both preoperatively and postoperatively.

Left ventricular mass (LVM), and mass index (LVMI) were calculated by formulas of Devereux and Reichek: LVM (g)=1.04 ([LVID+PWT+IVST]3-LVID3)'0.8+0.6

LVMI=LVM / BSA g/m2 (7).

Aortic regurgitation was classified by a proportional index to diameter of left ventricular out-flow tract (LVOT): < 25%: mild (1°), 25% to 46%: moderate (2°), 47% to 64%: moderate to severe (3°), > 65%: severe (4°) (8).

Statistical analyses were performed by SPSS/PC+ (ver 5.01) computer program. The probability (p) less than 0.05 was considered significant. The mean and standard error of mean values of all parameters were calculated and indicated. The consistency of proportional data was determined through chi-square test, corrected for continuity by "Fisher's Exact Test". "Mann Whitney U Test" and "The Wilcoxon Matched Pair Signed Rank Sum Test" were performed to compare the mean values of groups and to compare the differences between preoperative and postoperative values of parameters in each group. "The Spearman Correlation Analysis" was performed to evaluate the relation among variables.

Results

There was not any mortality or significant morbidity in both groups. All patients were in NYHA class I and symptom free at the follow up.

Echocardiographic Evaluations

There was no statistical difference regarding all echocardiographic examinations between corresponding sizes of different prosthetic valve types ($p>0.05$, paired t test).

The LVEDd, LVEDs, LVM and LVMJ measurements of both groups showed significant reductions postoperatively (pO.OOl). Moreover, the reductions in LVM (247.3±76.7 g versus 330.51±103.0g) and LVMI (144.8±40.9g/m^2 versus 179.7±50.9 g/m^2) values of homograft group were more significant than those of prosthetic group ($p<0.05$) (Table 2 and Figure 1).

There was not any significant difference in LAD measurements of both groups. Likewise, heart rates (beats/min) of both groups were similar (85.75±11.85 and 83.44±16.80 for homograft and prosthetic groups, respectively).

The IVS thickness (1.20±0.29 mm preoperative^ versus 1.09±0.2 mm postoperatively, $p<0.05$), PW thickness (1.18±0.29 mm preoperative^ versus 1.08±0.16 mm postoperatively, $p<0.05$), and aortic root diameters (3.26±0.58 mm

Table 2. The preoperative and postoperative hemodynamic variables of patients at rest. The mean and standard error of mean (SEM) values of parameters were indicated. (Preop: preoperative, Postop: postoperative follow up, LVEDd: left ventricular diastolic diameter-cm, LVEDS: left ventricular systolic diameter-cm, LAD: left atrium diameter-cm, IVS: interventricular septum thickness-cm, PW: posterior wall thickness, Max. PG: maximum transaortic valve pressure gradient-mm Hg, LVM: left ventricular mass-g, LVMI: left ventricular mass index-g/m^2, AR: aortic regurgitation, Acc: MR: accompanying mitral regurgitation, HR: heart rate-beats/min)

	Homograft			Prosthetic			Intergroup p	
	Preop.	Postop.	p	Preop.	Postop	p	Preop.	Postop.
LVEDd	5.58±0.84	4.63± 0.50	<0.001	6.56± 8.48	5.28± 1.84	<0.001	NS	NS
LVEDs	3.86± 0.96	3.08±0.50	<0.001	6.00± 1.11	4.81± 0.70	<0.001	NS	NS
LAD	3.70± 0.75	3.65±0.75	NS	4.47± 1.61	4.44± 0.73	NS	NS	NS
IVS	1.20± 0.29	1.09± 0.20	<0.05	1.32± 0.24	1.31± 0.21	NS	NS	<0.01
PW	1.18±0.29	1.08±0.16	<0.05	1.26±0.18	1.25± 0.15	NS	NS	<0.01
Aortic root	3.26± 0.58	2.99± 0.43	<0.05	3.64±0.54	3.71±0.56	NS	NS	<0.001
Max. PG	27.3± 14.8	15.0± 9.7	NS	46.4± 42.9	17.06±7.22	O.05	NS	NS
Mean PG	12.3± 9.7	6.9± 6.03	NS	27.9± 18.6	7.91± 5.34	<0.05	NS	NS
EF	52.8± 5.5	56.1±5.1	<0.05	56.3± 10.5	56.87± 5.02	NS	NS	NS
LVM	386.3± 161.4	247.3± 76.7	<0.001	476.9± 167.6	330.51± 103.0	<0.001	NS	<0.05
LVMI	226.5± 160.2	144.9* 40.6	<0.001	260.3± 87.9	179.7± 50.9	<0.001	NS	<0.05
AR	3.13± 0.50	0.81± 1.11	<0.001	2.94±0.93	0.25± 0.24	<0.001	NS	NS
Acc. MR	0.94± 1.06	0.31± 0.60	<0.05	1.00± 0.73	0.38± 0.62	<0.01	NS	NS
HR	89.94± 15.26	85.75± 11.85	NS	85.00±11.85	83.44± 16.80	NS	NS	NS

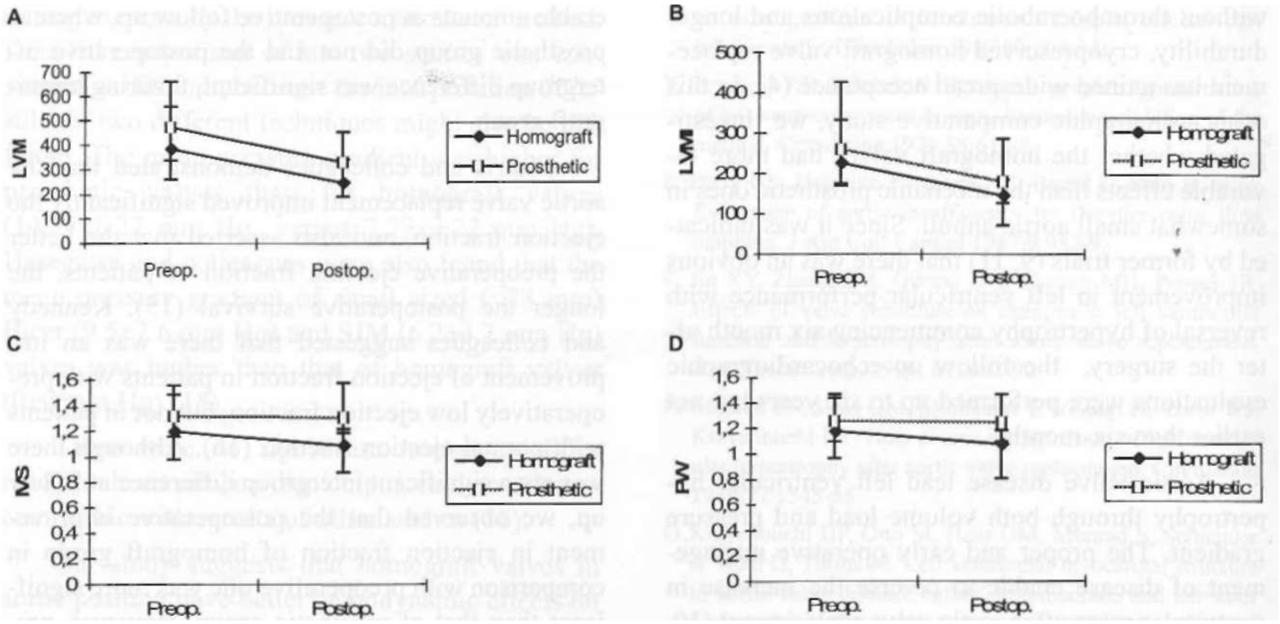

Figure 1. Alterations in echocardiographic parameters showing significant intergroup differences.(Preop: preoperative, Postop: postoperative, LVM: left ventricular mass-g, LVMI: left ventricular mass index-g/m^2, IVS: interventricular septum-cm, PW: posterior wall-cm.)

preoperatively versus 2.99±0.43 mm postoperatively, p<0.05) of homograft group were showed significant reductions with significant improvements in EF measurements (52.8%±5.5% preoperatively versus 56.1%±5.1% postoperatively, p<0.05) at postoperative follow up , whereas prosthetic group did not show such important changes (Table 2 and Figure 1).

The observed reductions in maximum systolic transvalvular pressure gradient (27.3±14.8mm Hg versus 15.0±9.7mm Hg) and in mean systolic pressure gradient (12.3±9.7 mm Hg versus 6.9±6.03mm Hg), of homograft group were not statistically significant, whereas those of prosthetic group (46.4±42.90 mm Hg preoperatively versus 17.06±7.22 mm Hg postoperatively; p<0.05 and 27.9±18.6 mm Hg preoperatively versus 7.91±5.34 mm Hg postoperatively; p<0.05 as maximum and mean PGs, respectively) were significant (Table 2). However, mean PGs of both groups were similar (6.9±6.03mm Hg versus 7.91±5.34 mm Hg).

There were no significant intergroup differences in cardiac index (CI) (2.71±1.54 L.min-1.m-2 and 2.58±1.49 L.min-1.m-2 for homograft and prosthetic groups, respectively) Likewise, cardiac output (CO) measurements were similar (4.59±2.66 L.min-1 and 4.73±2.70L.min-1 for homograft and prosthetic groups, respectively).

Mean AVA measurements of both groups did not show a significant difference (2.0±0.74cm2 and 1.92± 1.07 cm2 for homograft and prosthetic groups, respectively).

Although the mean degree of aortic regurgitation reduced significantly at follow up in comparison with preoperative values, and trivial aortic regurgitation was detected in both homograft (3.13±0.50 versus 0.81±1.11, pO.001) and prosthetic group (2.94±0.93 versus 0.25±0.24, p<0.001), there was not any significant difference between two groups (Table 2).

We also detected the degree of concomitant mitral regurgitation of both groups reduced significantly at follow up (0.94±1.06 versus 0.31±0.60 at follow up; p<0.05 and 1.00±0.73 versus 0.38±0.62 at follow up; p<0.02 for homograft and prosthetic groups, respectively). However, intergroup difference was not significant (Table 2).

Discussion

Because of its clearly demonstrated superiorities, such as excellent hemodynamic performance without thromboembolic complications and longer durability, cryopreserved homograft valve replacement has gained widespread acceptance (4). In this echocardiographic comparative study, we investigated whether the homograft valves had more favorable effects than the mechanic prosthetic ones in somewhat small aortic annuli. Since it was indicated by former trials (9, 11) that there was an obvious improvement in left ventricular performance with reversal of hypertrophy commencing six month after the surgery, the follow up echocardiographic evaluations were performed up to six years but not earlier than six-month.

Aortic valve disease lead left ventricular hypertrophy through both volume load and pressure gradient. The proper and early operative management of disease enable to reverse the increase in ventricular mass after aortic valve replacement (10, 11). Krayenbuehl and colleagues showed that the decrease of muscle mass at the intermediate time after valve replacement is mediated by regression of myocardial cellular hypertrophy in patients with aortic stenosis and aortic insufficiency, and in addition by a decrease of fibrous content in patients with aortic insufficiency. Late after surgery, left ventricular fibrous content also decreases in patients with aortic stenosis (11). A similar reduction in ventricular mass and mass indices occurred in both homograft and prosthetic valve replaced groups was demonstrated in this study, also (Table 1). However, the mean reduction in both ventricular mass and mass indices of homograft group was more significant than that of prosthetic group. This conclusion suggests that homograft valves have more favorable effects on ventricular hypertrophy than the prosthetic ones.

Bonow and coworkers demonstrated that there was a progressive decrease in LVEDd measurements from postoperative 2nd week up to 6 to 8th months (12). Our echocardiographic evaluations also showed significant decreases of LVEDd and LVEDs measurements of both groups, however, there was not any significant difference between two groups. Moreover a significant regression in thicknesses of IVS and PW subsequent to aortic valve replacement was also indicated some former studies (13, 14). However, in our study only homograft group showed such desired reversal in considerable amounts at postoperative follow up, whereas prosthetic group did not and the postoperative intergroup difference was significant, favoring homograft group.

Morris and colleagues demonstrated that the aortic valve replacement improved significantly the ejection fraction, and also asserted that the better the preoperative ejection fraction of patients, the longer the postoperative survival (15). Kennedy and colleagues suggested that there was an improvement of ejection fraction in patients with preoperative^ low ejection fraction, but not in patients with normal ejection fraction (16). Although there was not a significant intergroup difference at follow up, we observed that the postoperative improvement in ejection fraction of homograft group in comparison with preoperative one was more significant than that of prosthetic group. However, preoperative relatively lower ejection fraction of homograft group must be considered in interpretation of this result, as indicated by Kennedy and colleagues.

Some authors found that no pressure gradient through the homograft valve exists at rest at postoperative period (2, 17), whereas a pressure gradient, somewhat trivial, changing between 1.5 to 4.2 mm Hg was remained after mechanic valve operations (18). In our study both groups had similar pressure gradients after the operation (6.9±6.03 mm Hg and 7.91±5.34 mm Hg for homograft and prosthetic groups, respectively). However, only prosthetic group showed significant reduction of pressure gradient at postoperative period in comparison with preoperative values that were higher than those of homograft group. Because of lacking of a significant intergroup difference, this result could not be interpreted as superiority of prosthetic valves.

The results of former studies regarding pressure gradients of homograft valves were in a wide range, between 0 and 10 mm Hg. Using Doppler echocardiography, Jaffe and colleagues (2) reported that the mean pressure gradient for homograft valves was 5.9 to 6.7 mm Hg at rest and 8.1 to 9.7 mm Hg during exercise. Using cardiac catheterization, Hasegawa and colleagues (18) demonstrated that the mean pressure gradient for homograft valves was 0±0 mm Hg at rest and 0.5±2.0 mm Hg during exercise by the pressure manometer method. Detailed comparison of last two studies was considered as difficult, because the interpretation of results of two different techniques might also be different. The mean pressure gradient was higher for prosthetic valves than for homograft valves (14.94±6.22 mm Hg versus 7.29±3.22 mm Hg). Hasegawa and colleagues were also found that the mean pressure gradient of small sized (<23 mm) Bicer (9.5±7.6 mm Hg) and SJM (6.2±4.2 mm Hg) valves was higher than that of homograft valves (0±0 mm Hg)(18).

There were no significant intergroup differences in heart rate, cardiac output, cardiac index as compatible with results of other studies (18).

Our study suggests that homograft valves in aortic position have better hemodynamic effects on ventricular performances than the prosthetic ones, irrespective for prosthesis type, especially in patients with small aortic annuli.

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