CARDIAC VOLUME REDUCTION PROCEDURES

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We present our experience of two years on cardiac volume reduction in 26 patients who underwent left atrial resection (LAR) to reduce left atrial volume and maintain the sinus rhythm (in 20 patients: Group A), LAR and partial left ventriculectomy (PLV) (in 2 patients: Group B) and PLV to reduce left ventricular diameters with end-stage dilated cardiomyopathy (CMP) (in 4 patients: Group C). Etiological factors were recorded as rheumatic disease in Group A and as idiopathic dilated cardiomyopathy in Group B and C. Atrial fibrillation was observed in 20 patients, while 6 patients had normal sinus rhythm. Preoperatively, most of the patients in Group A were in New York Heart Association (NYHA) Class III, and except one all patients were in NYHA Class IV in Group B and C.

Preoperative echocardiographic assessment revealed LA thrombosis in 3 patients and LA spontaneous echo contrast (SEC) in 5 patients. Mean left atrium (LA) diameter was 8.03 cm in Group A and 8.40 cm in Group B. Mean left ventricle end systolic (LVES) diameter was found as 6.30 cm in Group B and 6.50 cm in Group C, while mean left ventricle end diastolic (LVED) diameter was found as 7.50 cm in Group B and 7.80 cm in Group C. Mean left ventricle ejection fraction (LVEF) was calculated as 29% in patients with dilated CMP.

LAR was performed in 22 patients (in Group A and Group B) and PLV was performed in 6 patients (in Group B and Group C). Cardiac autotransplantation technique was used in 8 patients (in Group A and Group B). Combined valvular procedures were required in 20 patients in Group A, in 2 patients in Group B and in 2 patients in Group C. Mean aortic cross-clamping time was 114±38 min and mean cardiopulmonary bypass time was 146±42 min.

None of the groups had an operative mortality. 3 patients were operated once again for bleeding. Hospital mortality was 7.7% due to renal and multi-organ failure (MOF) in 2 patients. Postoperatively, mean LA volume reduced by 68% in Group A and 81% in Group B, whereas mean LA diameter diminished by 45% both in Group A and B. Normal sinus rhythm was obtained in 11 of the 20 patients (55%) having atrial fibrillation after performing LAR. Mean LVESD of the patients reduced to 4.60 cm in Group B and 4.58 cm in Group C, while mean LVEDD reduced to 6.20 cm in Group B and 6.18 cm in Group C. Postoperatively, mean left ventricular ejection fraction changed from 29% to 45% in Group B and from 29% to 46% in Group C.

Total follow-up time was 264 patient-months. Postoperatively, most of the patients were in a better NYHA functional class and demonstrated a functional improvement. No left atrial thrombosis and/or left atrial spontaneous echo contrast was revealed in patients that underwent left atrial resection. These preliminary results demonstrated the advantages and usefulness of LAR for decreasing the risk of thromboembolic complications and restoring atrioventricular synchronicity, and beneficial effects of PLV on improving the prognosis of dilated CMP, in a way forming a bridge to cardiac transplantation.

Key words: atrial fibrillation, giant left atrium, volume reduction.

In spite of surgical correction of mitral valve disease, factors like atrial fibrillation (AF), giant left atrium (GLA) and low cardiac output (LCO) cause stagnation of blood in the left atrium (LA), leading to precipitation and subsequent left atrial thrombus formation (1). A GLA may apply pressure to the left ventricle, pulmonary vessels and/or bronchial tree. Different techniques such as para-annular plication or posterior wall plication were performed in order to reduce giant LA size (2). In 1991, "maze" procedure was described by James L. Cox in surgical treatment of atrial fibrillation (3-7). In 1996, R.J.V. Batista performed a series of surgical procedures by using cardiac autotransplantation technique in order to reduce left atrial volume in patients with AF and GLA (8). Partial left ventriculectomy (PLV) procedure was also performed by the same author in selected patients with dilated cardiomyopathy (CMP). The procedure was based on the principle of decreasing intracavitary pressure and wall stress by reducing the left ventricular diameter (9-11).

In the present study, 20 patients were included for investigating the clinical results of left atrial resection (LAR) (Group A), in addition, two patients who underwent combined atrial and ventricular resection procedure (Group B) and four patients with left ventricular resection were also included (Group C).

PATIENTS and METHODS

Between 1996 and 1998, 26 patients underwent a cardiac volume reduction procedure concomitant with their valve operation at Koşuyolu Heart and Research Hospital. There were 14 male and 12 female patients in the study group with a mean age 34.2 years (ranged from 19 to 63). 20 patients underwent LAR to reduce left atrial volume and maintain the sinus rhythm (Group A), while two patients underwent both LAR and PLV (Group B) and four patients with end-stage dilated CMP underwent PLV to reduce left ventricular diameter (Group C). Etiology of the patients' disorders was recorded as rheumatic in 20 patients, while there was idiopathic dilated CMP in 6 patients.

Of the 26 patients, three had undergone a prior cardiac operation. 18 had mitral regurgitation, four had mitral stenosis and four had mixed mitral disease. Nine patients had moderate to severe aortic insufficiency, while six patients had mild to severe tricuspid insufficiency. Atrial fibrillation was observed in 20 patients and 6 patients had normal sinus rhythm. Preoperatively, in Group A, most of the patients were in NYHA Class III and while in Group B and C all the patients were in NYHA Class IV except one (Table 1).

Preoperative assessment of the patients by echocardiography revealed left atrial thrombosis in 3 patients and left atrial spontaneous echo contrast (SEC) in 5 patients. Mean LA diameter was measured as 8.03 cm in Group A and 8.40 cm in Group B. Mean LA volume was calculated as 268±128 ml in Group A and 531.5 ml in Group B. GLA was observed in 22 patients (LA diameter ≥ 6.0 cm). There was LA thrombosis in three patients and LA spontaneous echo contrast (SEC) were found in five patients. Mean left ventricle ejection fraction (LVEF) was calculated as 29% in the patients with dilated CMP. Mean LVES diameter was found as 6.30 cm in Group B and 6.50 cm in Group C.

Table 1: Preoperative Clinical Status

	Group A (20 Pts)	Group B (2 Pts)	Group C (4 Pts)
Age (Mean)	34.6	35	53
Gender			
M	8	2	4
F	12		
Rhythm			
AF	18	2	
SR	2		4
NYHA			
Class I	0		
Class II	6		
Class III	13	1	
Class IV	1	1	4

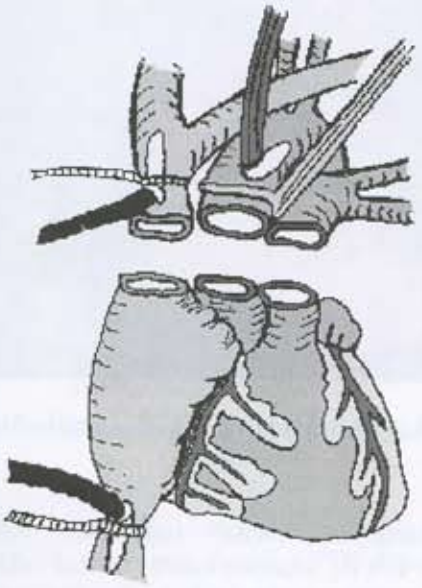

Figure 1. Cardiac autotransplantation technique.

while LVED diameter was 7.50 cm in Group B and 7.80 cm in Group C (Table 2).
Mean cardiac index was calculated as 1.78 l/m/m2. Of the six patients with dilated CMP in Group B and C, four had moderate to severe pulmonary hypertension. All of the six patients had moderate to severe mitral insufficiency. Additionally, three of them had tricuspid insufficiency and one patient had chronic renal failure.

SURGICAL TECHNIQUE

Atrial resection procedures

All patients were operated under cardiopulmonary bypass (CPB) in moderate hypothermia. CPB was initiated with aortic and double venous cannulation. Left ventricle was cut through the right superior pulmonary vein. Myocardial protection was obtained by continuous retrograde isothermic blood cardioplegia through the coronary sinus. Direct superior vena cava cannulation was performed in eight patients in whom cardiac autotransplantation was planned (Figure 1).
In nine patients, LAR was performed by removing two stripes of 4x10 cm including LA lateral wall and periannular area extending from the pulmonary vein orifices to mitral annulus. In addition, left atrial appendage (LAA) was plicated (Figure 2).
In eight patients, LA resection was extended from lateral wall to LAA including the left atrial roof, retaining the posterior wall surrounding the pulmonary vein orifices and the periannular area (Figures 3 and 4).
In eight patients, LA resection was performed by cardiac autotransplantation (Figure 1), huge LA was resected using the method displayed on Figure 3. Thus, the closure of the LA incisions were performed using a safer and easier way (Figure 5). In two patients, atrial

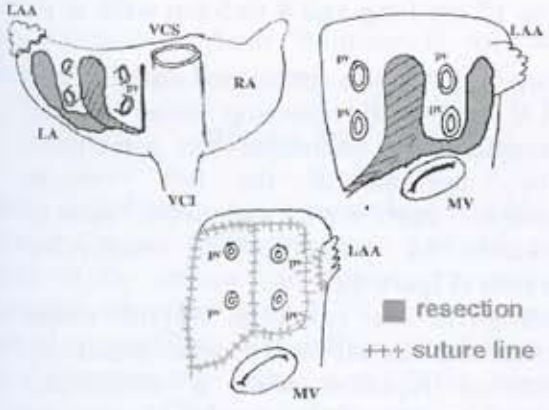

Figure 2. Partial LAR resection.

LA: left atrium, LAA: left atrial appendage, RA: right atrium, VCS: vena cava superior, VCI: vena cava inferior, MV: mitral valve

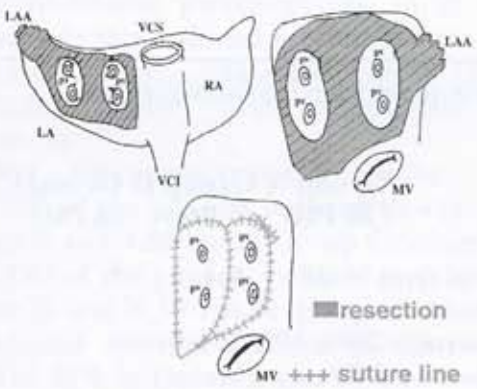

Figure 3. The extended partial LAR resection.

LA: left atrium, LAA: left atrial appendage, RA: right atrium, VCS: vena cava superior, VCI: vena cava inferior, MV: mitral valve

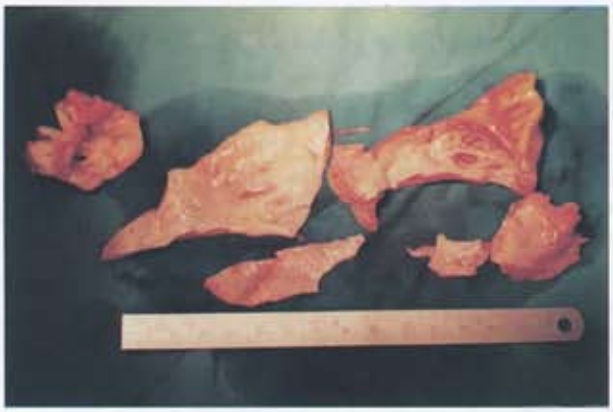

Figure 4. Resected LA wall specimens.

Figure 5. Performing LAR resection by autotransplantation technique.

Table 2. Preoperative echocardiographic findings.

	Group A (20 Pts)	Group B (2 Pts)	Group C (4 Pts)
LA Diameter (cm)	8.03	8.4	
LA Volume (ml)	268± 123	531.5	
SEC	5/20.	0	
Thrombus	3/20.	0	
LVEDV (ml)		303	309
LVESV (ml)		225	237
LVEDD (cm)		7.5	7.8
LVESD (cm)		6.3	6.5
LVSV (ml)		73	75
EF (%)		29	29

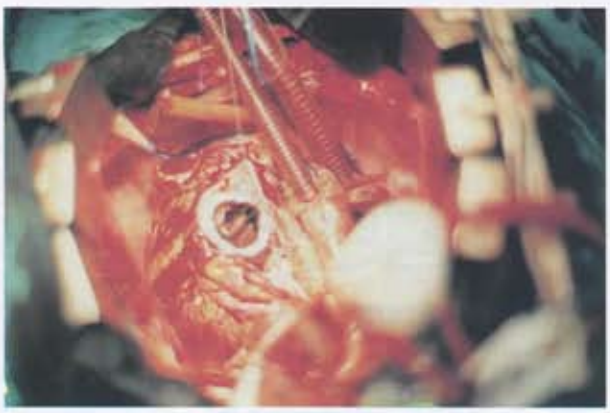

Figure 6. LAR and MVR autotransplantation technique.

septum aneurysm was resected. After performing LAR, concomitant mitral valve procedures were completed before LA closure (Figure 6). In Group A, combined valvular procedures were required in 20 patients (mitral valve replacement in 9 patients, mitral valve reconstruction in 11, aortic valve replacement in 3 patients, aortic valve reconstruction in 4 patients and tricuspid annuloplasty in 6 patients).

Ventricular resection procedures

In patients with dilated CMP (in Group B and C), the surgical procedure was aimed at reducing left ventricular volume by a triangular resection from the apex to the mitral annulus between the two papillary muscles (Figure 7). The resected myocardial segment was 9 to 12 cm long and 4 to 5 cm wide at its base.

In Group B, LAR was performed initially, and then LV free wall resection using cardiac autotransplantation technique was performed. The two portions of the left ventricle myocardium that were cut were sutured continuously by polypropylene reinforcing Teflon felts (Figure 8).

Depending on the condition of the mitral apparatus, the mitral valve was preserved, repaired, or replaced with a mechanical prosthesis. In Group B, combined valvular procedures were required in two patients (mitral valve replacement in one patient and mitroaortic reconstruction in another patient). In Group C, combined valvular procedures (mitral valve reconstruction) were required in two patients.

Figure 7. Partial left ventricular resection.

Figure 8. Completion of LV volume reduction procedure.

In eight patients, inotropic support was required in weaning from CPB. Intra-aortic balloon pump was used in six patients. The others were successfully weaned from CBP.

FOLLOW-UP PROTOCOL

After discharge, patients were followed monthly in terms of cardiac medication, rhythm and functional capacity. Doppler echocardiography, 24-hourly Holter monitor, chest roentgenograms were repeated at the first, third and sixth month after operation. A total of 11 patients in Group A and B who underwent prosthetic valve replacement received warfarin anticoagulation.

STATISTICAL ANALYSIS

Non-parametric Mann Whitney U test was used.

RESULTS

Mean aortic cross-clamping time was 114±38 min and mean CPB time was 146±42 min. None of the groups had operative mortality. Hospital mortality was 7.7% (two patients) due to renal failure and multi-organ failure in the postoperative first and fifth month, respectively. Three patients were operated again for bleeding. Temporary atrioventricular block (nodal rhythm) requiring temporary pacemaker application was recorded in two patients.

Doppler echocardiography was used to evaluate the cardiac function and to measure the cardiac chambers of patients who underwent cardiac volume reduction procedure.

During the postoperative course, no left atrial thrombosis and/or left atrial spontaneous echo contrast occurred in patients that underwent LAR. Mean LA diameter was 4.41cm in Group A and 4.60 cm in Group B. Mean LA volume was 85ml in Group A and 97 ml in Group B. Echocardiographic measurements in follow-up showed a marked decrease in LA diameters and volumes (Figures 9a and 9b). Postoperatively, mean LA volume reduced by 68% in Group A and 81% in Group B, whereas mean LA diameter diminished by 45% both in Group A and B (Table 3). After performing LAR, normal sinus rhythm was obtained in 11 of the 20 patients (55%) having atrial fibrillation preoperatively. In all of the 11 patients that returned to sinus rhythm, atrial A-wave was obtained in Doppler echocardiography from transmitral flow (Table 4).

During the postoperative course, mean LVESD of the patients reduced to 4.60 cm in group B and 4.58 cm in Group C, while mean LVEDD of the patients reduced to 6.20 cm in group B and 6.18 cm in group C. Mean left ventricular ejection fraction increased from 29% to 45% in Group B and 46% in Group C. Mean left ventricle end-systolic volume (LVESV) decreased to 93.40 ml in Group B and 95.40 ml in Group C, while mean left ventricle end-diastolic volume decreased to 182 ml in Group B and 188 ml in Group C (Table 3). Mean cardiac index increased from 1.78 l/m/m2 to 2.41 l/m/m2. All of the

Table 3. Postoperative echocardiographic findings.

	Group A (20 Pts)	Group B (2 Pts)	Group C (4 Pts)
LA Diameter (cm)	4.41	4.60	
LA Volume (ml)	85	97	
SEC	-	-	
Thrombus	-	-	
LVEDV (ml)		182	188
LVESV (ml)		93.4	95.4
LVEDD (cm)		6.20	6.18
LVESD (cm)		4.60	4.58
LVSV (ml)		92	92
EF (%)		45	46

surviving patients in Group A showed an improvement in NYHA functional class, with an average improvement of from 2.8 preoperatively to 1.2. In Group B and C, although one of the surviving patients showed no improvement in NYHA functional class, average NYHA functional class improved from 3.8 preoperatively to 1.8 postoperatively (Figure 10). In the sixth month of the postoperative course, average NYHA functional class changed to 2.5 in patients who underwent Batista procedure.

Total follow-up time was 264 patient-months. On follow-up, there was one late death (sudden death) leading to an actuarial survival rate of 84% in 12 months.

Table 4. Postoperative clinical status.

	Group A (20 Pts)	Group B (2 Pts)	Group C (4 Pts)
Op. Mortalite	–	–	–
Rhythm			
AF	7	–	–
SR	13	2	4

DISCUSSION

Atrial fibrillation is a common arrhythmia associated with significant morbidity and increased mortality, partly due to the increased risk of stroke (12,13). The increased risk of thromboembolism makes continuous anti-coagulation necessary, while the absence of atrial contraction worsens the hemodynamic situation (14-16). The majority of the patients who underwent an operation for mitral valve disease with chronic AF do not recover sinus rhythm with conventional postoperative treatment. The size of the LA is a major factor in the initiation and continuation of atrial fibrillation(17-19).

Several medical, interventional treatments and surgical techniques like maze procedure, ablation of atrial fibrillation with LAR and pulmonary vein isolation are used to treat AF. Recently, surgical therapy of atrial fibrillation

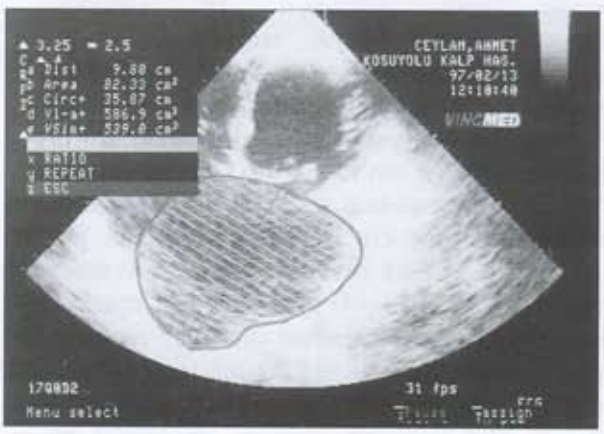

Figure 9a. Preoperative echo of a patients with giant LA.

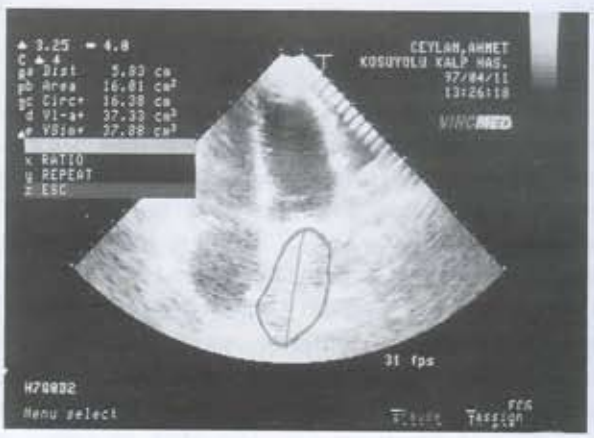

Figure 9b. Postoperative echo of the same patient after LAR.

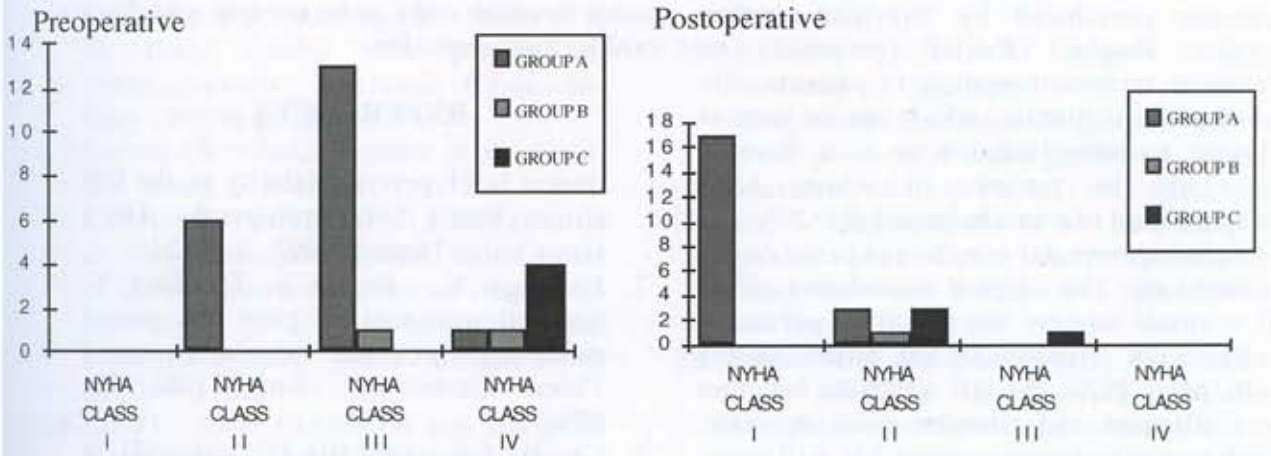

Figure 10. Preoperative and postoperative functional status.

for reducing the left atrium size with "maze" procedure and/or left atrial resection, gained wide acceptance (20). Paraannular and lateral wall plication techniques offered ways to diminish the LA size, and thus, remove the pressure applied to the surrounding tissues (21). However, these techniques are not suitable for reducing the LA volume and spontaneous echo contrast (SEC)/thrombus risk, since neither LA volume reduction nor restoration of sinus rhythm in postoperative course was not observed in any of the patients who underwent the plication operation.

The maze procedure cures AF; however, it isolates the pulmonary vein area and results in discordant activation in certain adjacent LA segments, which affects the LA function. In the literature, the probability of recovering sinus rhythm after maze procedure is between 40% and 70% (22-24). There were instances of sinoatrial nodal dysfunction that resulted in sick sinus state and atrial pace insertion was needed in 40% of the cases (3-6). To preserve a more physiologic atrial conduction, maze procedure should not be performed in patients who have an enlarged LA or in complex cases requiring relatively longer operation time (25). LAR presents a solution not only for the reduction of the LA diameter and volume but also for the restoration of sinus rhythm. Our results in LAR indicated that mean left atrial volume reduced by 68% in Group A and 81% in Group B, whereas mean LA diameter diminished by 45% both in Group A and B.

Of the 20 patients with AF who underwent LAR, 11 recovered sinus rhythm postoperatively. None of the cases required permanent pace implantation in the present series. Autotransplantation was performed in eight patients associated with LAR. We realized that autotransplantation could provide wider resections and safer LA suturing.

Cardiac transplantation is the treatment of choice for refractory cardiac failure, but, limited number of donors, complications inherent in transplantation procedure and relative and absolute contraindications has made it necessary to find alternative surgical solutions. More recently, transmyocardial laser revascularization, implantation of mechanical assist devices, implantable cardioverters/ defibrillators and dynamic latissimus dorsi cardiomyoplasty were introduced into clinical practice, and are still under evaluation (26-28). For most of the patients suffering from congestive heart failure, cardiac transplantation is the only therapeutic option. However, patient age, decreasing number of donors, mortality while the patient was on the waiting list, high morbidity under immunosuppressive therapy and graft

vasculopathy are the problems of this therapeutic strategy.

Partial left ventriculectomy (the Batista procedure), a new organ preserving surgical technique introduced by Brazilian cardiac surgeon Randas Batista proposes an alternative treatment strategy in patients with end-stage heart disease, which can be used as a bridge to transplantation or as a therapy, particularly in patients in whom heart transplantation is contraindicated (8,9,29).

Partial left ventricular resection is based on the Laplace Law. The surgical remodeling of the left ventricle restores the abnormal geometric configuration produced by the dilated failing heart. After PLV, the left ventricle becomes more elliptical and chamber sizes decrease, which results in lower regional LV wall stress and less myocardial stiffness. A more elliptical shape may improve systolic LV performance by decreasing regional LV afterload (e.g. systolic wall stress), which would thereby lower myocardial oxygen consumption and improve LV pump efficiency (30). Whichever alternative method is tested, there is a significant functional improvement but the cardiac output does not always increase (31). The advantage of PLV is obvious, since there is no waiting list, positive functional results have been demonstrated in wisely selected cases, and if necessary, secondary orthotopic cardiac transplantation is always possible.

In the present series, cardiac transplantation was contraindicated due to severe pulmonary hypertension in three patients and chronic renal failure in one patient. Partial left ventriculectomy provided a more rational solution for these patients.

Batista reported over 400 operations using partial left ventriculectomy. The Cleveland Clinic series reported results in 53 cases with a survival rate of 82% in one year.

Further studies on dilated cardiomyopathy and the decision to consider alternative surgical procedures versus cardiac transplantation will likely be determined by biomolecular studies. There are no comparative, prospective, randomized studies and strict selection of patients is required, which is a problem not yet resolved for all indications.

These preliminary results demonstrated the advantages and benefits of cardiac volume reduction procedures. These procedures decrease stagnation of blood in LA and the risk of thromboembolic complications, restore atrioventricular synchronicity, improve LV pump function and can be used as a bridge to cardiac transplantation.

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