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Echocardiographic Evaluation of Orthotopic Heart Transplantation: Single-Center Experience

Neda Behzadnia [1]; Babak Sharif Kashani [1]; Mohsen Mirhosseini [1]; Ahmadreza Moradi [1]; Golnar Radmand [2]; Zargham Hossein Ahmadi [1,*]

[1]Lung Transplantation Research Center, National Research Institute of Tuberculosis and Lung Disease (NRITLD), Shahid Beheshti University of Medical Sciences, Tehran, IR Iran
[2]Tobacco Prevention and Control Research Center, National Research Institute of Tuberculosis and Lung Disease (NRITLD), Shahid Beheshti University of Medical Sciences, Tehran, IR Iran

*Corresponding author: Zargham Hossein Ahmadi, Lung Transplantation Research Center, National Research Institute of Tuberculosis and Lung Disease (NRITLD), Shahid Beheshti University of Medical Sciences, Tehran, IR Iran. Tel: +98-9131404088, Fax: +98-2126109848, E-mail: zargham.ahmadi@gmail.com

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Background: In patients with advanced heart failure, significant improvement in pharmacological and non-pharmacological treatment strategies has conferred better survival rates and quality of life.
Objectives: This is a report on echocardiographic findings in heart transplantation (HTx) patients in their first 5 postoperative months.
Patients and Methods: Twenty patients undergoing HTx between September 2009 and July 2010 whose clinical and echocardiographic findings had been registered monthly for 5 months after HTx were enrolled.
Results: Eleven males and five females at a mean age of 33 years [range = 17-58 years] were enrolled in the study. The mean of the left ventricular ejection fraction (LVEF) was 52 ± 8.2 % and 58 ± 2.5 % on the first day and at 5 months after HTx, respectively. There was no LV enlargement at 5 months' follow-up. The right ventricle (RV) was mildly enlarged, but the reduced baseline RV function showed improvement at the 5th postoperative month (mean TAPSE was 11.7 ± 3.3 mm on the first post-HTx day versus 17.2 ± 6.3 mm after 5 months; $P < 0.005$). The pulmonary arterial pressure was slightly elevated at baseline, and it showed no significant decrease 5 months after HTx. More than 90% of the cases showed only mild tricuspid regurgitation at 5 months' follow-up. The tissue Doppler imaging-derived velocities of the medial and lateral mitral annuli and the tricuspid annulus demonstrated a gradual increment during the follow-up and reached their highest value at 5 months' follow-up.
Conclusions: The cardiac grafts at 5 months' post-HTx follow-up were characterized by normal LV dimensions and EF. Also, RV dysfunction and tricuspid regurgitation were frequent findings, but they were not associated with the clinical signs of congestive heart failure, morbidity, and mortality in the majority of our patients.

Keywords: Heart Transplantation; Echocardiography; Indices

1. Background

In patients with advanced heart failure, significant improvement in pharmacological and non-pharmacological treatment strategies has conferred better survival rates and quality of life (1). However, the left ventricular (LV) function usually remains severely depressed, and long-term follow-up is not yet available on many treatment modalities. In contrast to the more recently developed therapeutic options, heart transplantation (HTx) was introduced into broad clinical use 30 years ago and might be considered the gold standard for adequately selected patients (2-7). Even so, beyond survival rates, little is known about follow-up echocardiographic findings on HTx (8-10). We herein report the echocardiographic findings on HTx patients in our center.

2. Objectives

This is a report on echocardiographic findings in heart transplantation (HTx) patients in their first 5 postoperative months.

3. Patients and Methods

Among patients undergoing HTx at Masih-Daneshvari Heart Transplantation Center between September 2009 and July 2010, those who had regular follow-up sessions and whose clinical and echocardiographic findings had been registered monthly for 5 months after HTx were enrolled.

3.1. Echocardiographic Examination

All the recipients underwent standard evaluations, consisting of echocardiography, electrocardiography, and routine lab tests on each visit. Echocardiographic evaluations were performed using a SonoSite MicroMaxx ultrasound imaging system with a 2.5-MHZ transducer from a standard window and views in the left lateral

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position. All the echocardiographic studies were performed by a single echocardiographer. Atrial and ventricular dimensions, atrial areas, and ejection fraction (EF) were measured. Additionally, valvular competence was evaluated via color Doppler echocardiography, and the right ventricular (RV) size and function were assessed using tricuspid annular plane systolic excursion (TAPSE). Furthermore, the pulsed-wave Doppler technique was employed to measure the E,A velocity of the mitral and tricuspid valves, and tissue Doppler imaging (TDI) was used to measure the medial and lateral mitral annuli and the tricuspid annulus for the estimation of S, E`, A` velocity and calculation of the right and left myocardial performance index (MPI). MPI were used as a useful method for the baseline and serial follow up measurements RV the function and was calculated based on the following formula:

MPI = TCO - ET /ET

TCO (The tricuspid closure opening time) , (ET) Ejection time.

All echocardiographic measurement and calculations were done based on the latest American Society of Echocardiography guidelines. The study was approved by the institutional ethics committee, and informed consent was obtained from all the patients.

3.2. Statistical Analysis

All the statistical analyses were performed using IBM SPSS Statistics 19 for Windows (IBM Corp., Armonk, NY, USA). The data were assessed for normal distribution using the Kolmogorov-Smirnov test. The quantitative variables are presented as mean (standard deviation) and the categorical variables as counts and percentages. Paired t test or its non-parametric equivalent, Wilcoxon signed-rank test was used, as appropriate, to compare the quantitative variables.

4. Results

A total of 20 patients (65 % male) underwent HTx between September 2009 and July 2010.The mean age of the study population at the time of HTx was 33 years (range = 17-58 years), and the mean age of the donors was 26.7 ± 6.7 years (range = 17-40 years). The indications for HTx were comprised of dilated cardiomyopathy in 15 (75 %) patients, ischemic cardiomyopathy in 2 (10 %), arrhythmogenic RV dysplasia in 2 (10 %), and valvular heart disease in one (5 %) (Table 1). The transplantation technique was bicaval anastomosis in all the patients, and immunosuppressive therapies were initiated and continued in accordance with the 2010 International Society of Heart and Lung transplantation guidelines (11). All the patients were continuously and closely monitored by our transplantation clinic staff. Any complications such as hypertension, renal dysfunction, and infections were registered and managed by the transplantation team in Masih-Daneshvari Heart Transplantation Center. Three patients (2 females and one male) died because of disseminated intravascular coagulation and intracranial hemorrhage during the first postoperative week. Among the 20 patients, 17 patients were alive for 16 months and 16 patients had regular follow-up sessions and their clinical and echocardiographic findings were registered monthly for 5 months. During the 5-month follow-up period, none of the patients was symptomatic in terms of dyspnea. There were some complications such as asymptomatic acute cellular rejection (proven by endomyocardial biopsy), inferior vena cava stenosis, pulmonary emboli, massive pericardial effusion, diabetes mellitus, and renal failure, all of which were successfully addressed.

4.1. Echocardiographic Findings

4.1.1. Chamber Study and Ventricular Function

Table 2 depicts the chamber study findings on the

Table 1. Characteristics of the Heart Transplantation Recipients

Characteristics	Descriptive Index
Age, yr	
Mean	33.6
Range	17-58
Sex, No. (%)	
Male	13 (65)
Female	7 (35)
Transplantation cause, No. (%)	
Dilated cardiomyopathy	15 (75)
Ischemic cardiomyopathy	2 (10)
Arrhythmogenic right ventricular dysplasia	2 (10)
Valvular cardiomyopathy	1 (5)
Donor age	
Mean ± SD	26.73 ± 6.74
Range	17-40
Early in-hospital mortality, No. (%)	3 (15)
Major postoperative complications [a]	6
Previous implantable cardioverter-defibrillator	3 (15)
Transplantation technique	
Bicaval, %	100

[a] Major postoperative complications include new-onset diabetes mellitus, inferior vena cava stenosis, pulmonary thromboemboli, recurrent pericardial effusion, renal insufficiency, and atrial flutter (each in one patient).

first post-HTx day and at 5 months' follow-up. The LV dimensions, i.e. left ventricular end-diastolic dimension (LVEDD) and left ventricular end-systolic dimension (LVESD), were within the normal range. The mean LVEDD was 4 ± 0.5 cm on the first post-HTx day and 4.5 ± 0.7 cm at 5 months' follow-up (P > 0.05). The mean LVESD was 2.8 ± 0.7 on the first post-HTx day and 3 ± 0.6 cm at 5 months' follow-up. The left atrial area was 17.1 ± 6.2 cm^2 on the first postoperative day and 22.1 ± 7.5 cm^2 after 5 months. The right atrial area was within the normal range: 15.2 ± 3.7 cm^2 early after HTx and 15.4 ± 4.2 cm^2 at 5 months' follow-up. The RV dimension was 3 ± 0.5 cm on the first post-HTx day with no change to 2.9 ± 0.5 cm at 5 months' follow-up. The LVEF, the index of the systolic function, was preserved and normal in all the patients. The RV dysfunction as assessed by TAPSE and peak S velocity was significantly reduced in the early postoperative period (11.7 ± 3.3 mm and 5.5 ± 0.5 cm/sec) and showed improvement during our 5-month follow-up period (17.2 ± 6.3 mm and 9.5 ± 3.1 cm/sec) (Figure 1 and 2). Pulmonary arterial pressure was only mildly elevated after HTx (36.4 ± 6.6 mmHg early and 37.2 ± 7.1 mmHg at 5 months' follow-up) (Figure 3 and 4).

4.1.2. Doppler and Tissue Doppler Study

Table 3 presents the Doppler and TDI findings on the first post-HTx day and at 5 months' follow-up (12). The mean isovolumic relaxation time was 68 ± 32 msec early after HTx and 61 ± 7.3 msec 5 months after transplantation. The mean mitral E-wave deceleration time was 162.7 ± 39 msec early after HTx and reached 150 ± 32 msec 5 months later. The TDI-derived MPI was 0.97 ± 0.54 early after HTx and 0.66 ± 0.17 at 5 months' follow-up for the left-sided MPI, and 0.79 ± 0.34 early after HTx and 0.79 ± 0.27 at 5 months' follow-up for the right-sided MPI (13) (Figure 5).

4.2. Valvular Function Assessment

The assessment of valvular competence revealed tricuspid regurgitation > mild grade in 38.5 % of the patients on the first post-HTx day and 6.2% at 5 months' follow-up. There was no pericardial effusion (PE) in 66 % of the patients, whereas 25 % had mild PE, 9 % had moderate PE, and 0 % had large PE 5 months following HTx. The TDI-derived velocities of the medial and lateral mitral annuli and the tricuspid annulus exhibited a gradual increment during the follow-up and reached their highest value 5 months after HTx (Figure 6 and 7). The mean E/E` ratio, a marker of the LV filling pressure, was normal in the early phase and demonstrated no change at 5 months' follow-up (9.3 ± 2.9 vs. 7.8 ± 2.1; P = 0.15).

Table 2. Echocardiographic Indices Showing the Cardiac Chamber Size and Function in the Heart Transplantation Recipients at 5 Months' Follow-up

Variable	First Day	5th Month	P Value
Ejection fraction, %	52 ± 8.23	58 ± 2.58	0.027
End-diastolic diameter, cm	4 ± 0.5	4.55 ± 0.79	0.454
End-systolic diameter, cm	2.86 ± 0.71	3.08 ± 0.67	0.722
Left atrial area, cm^2	17.1 ± 6.27	22.1 ± 7.53	0.463
Right atrial area, cm2	15.2 ± 3.79	15.4 ± 4.29	0.415
Right ventricular size, cm	3.04 ± 0.54	2.92 ± 0.53	0.397
Tricuspid annular plane systolic excursion, mm	11.75 ± 3.32	17.25 ± 6.36	0.014
Pulmonary arterial pressure, mmHg	36.4 ± 6.6	37.22 ± 7.12	0.385
Tricuspid S velocity, cm/sec	5.5 ± 0.5	9.5 ± 3.1	0.013
Moderate/Severe tricuspid regurgitation, %	38.5	6.2	0.125
Pericardial effusion, %	53.4	34	0.153

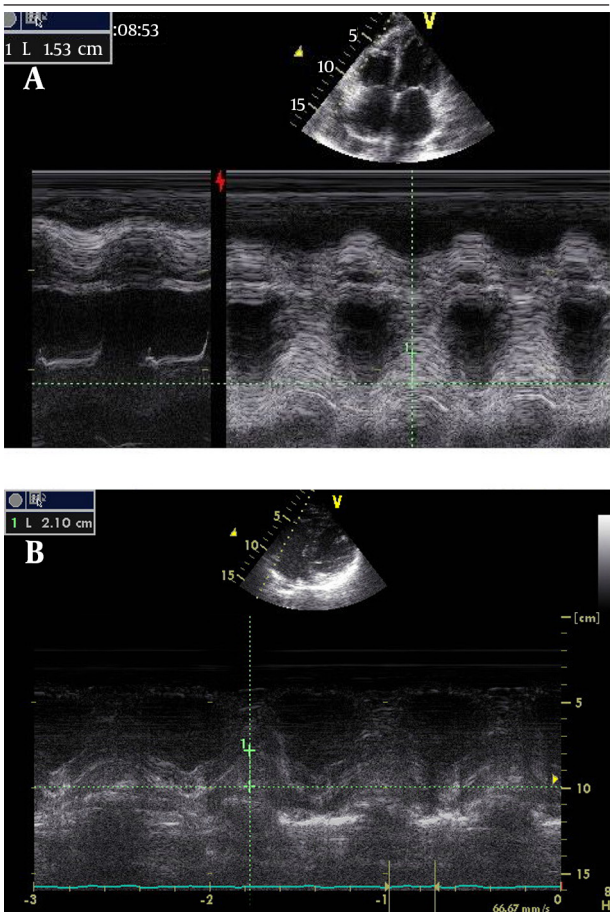


Figure 1. Upper: First post-Heart Transplantation Tricuspid Annular Plane Systolic Excursion, Lower: Tricuspid Annular Plane Systolic Excursion 5 Months After Heart Transplantation

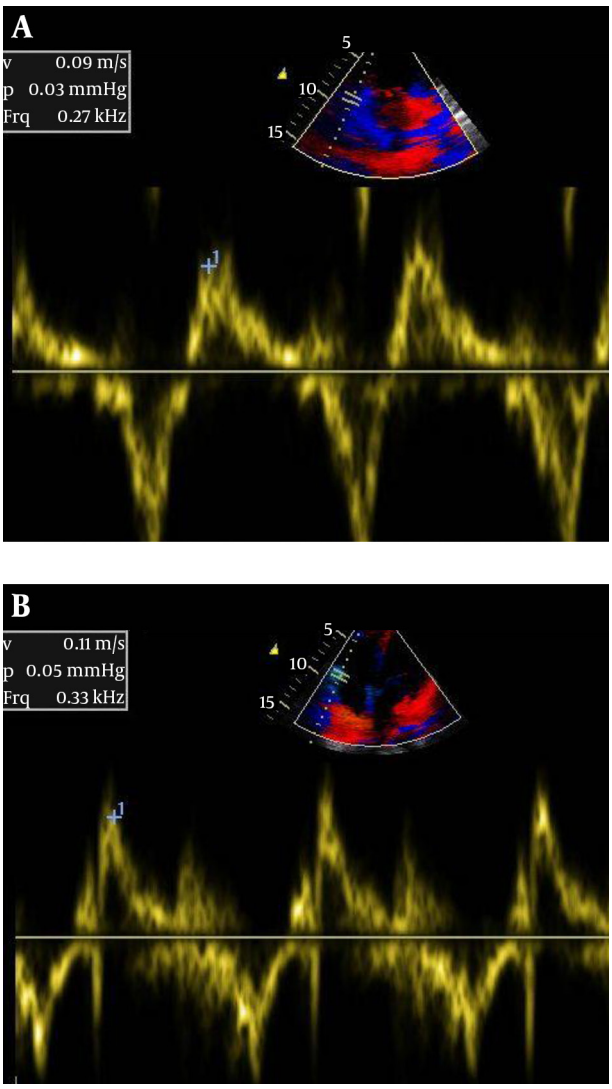


Figure 2. Upper: first month post HTX Tricuspid systolic or S velocity, Lower: Tricuspid S velocity 5 months after HTX

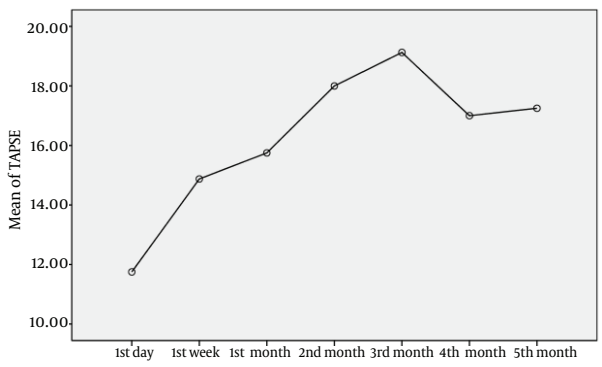


Figure 3. Diagram Showing Changes in Tricuspid Annular Plane Systolic Excursion during a 5-Month Follow-up period

Table 3. Doppler/Tissue Doppler Echocardiographic Indices in the Heart Transplantation Recipients at 5 Months' Follow-up [a]

Variable	First Day	5th Month	P Value
DT, msec	162.77 ± 39	150 ± 32	0.986
IVRT, msec	68 ± 32	61 ± 7.3	0.319
E/E` ratio	9.3 ± 2.9	7.8 ± 2.1	0.151
LV MPI	0.97 ± 0.54	0.66 ± 0.17	0.385
RV MPI	0.79 ± 0.34	0.79 ± 0.27	0.108
Medial mitral annulus E` velocity, cm/sec	7.7 ± 1.8	11.3 ± 4.1	0.015
Medial mitral annulus A`, cm/sec	5.4 ± 2.8	9.1 ± 2.2	0.003
Medial mitral annulus S velocity, cm/sec	6.6 ± 1.8	8.8 ± 1.6	0.016
Lateral mitral annulus E` velocity, cm/sec	5.7 ± 1.8	7.7 ± 4.2	0.651
Tricuspid E` velocity, cm/sec	5.6 ± 1.3	10.5 ± 2.3	0.014
Tricuspid A` velocity, cm/sec	5.5 ± 2.4	8.5 ± 2.4	0.213

[a] Abbreviations: EF, Ejection Fraction; RV, Right Ventricle; LV and RV MPI, Left Ventricular and Right Ventricular Myocardial Performance Index; DT, Deceleration Time; IVRT, Isovolumic Relaxation.

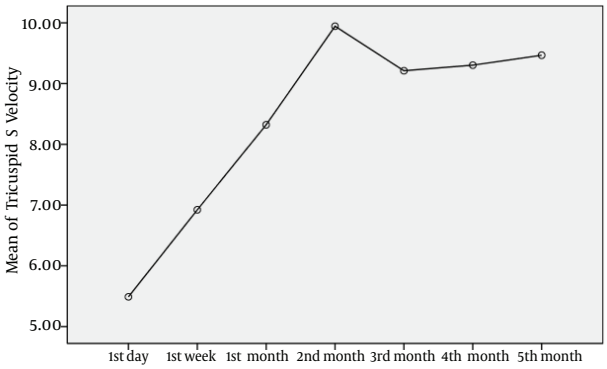
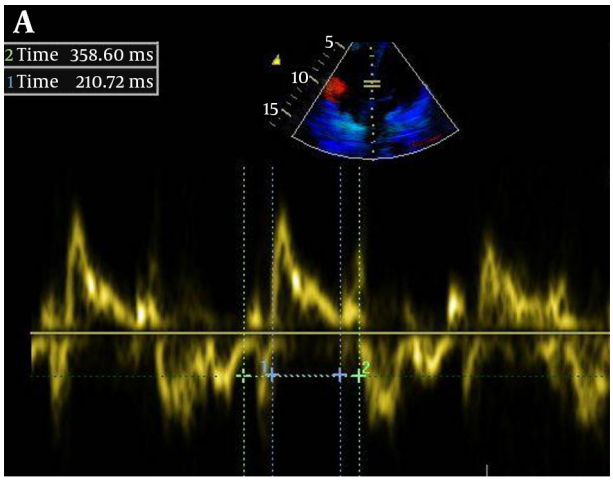


Figure 4. Diagram Showing Changes in Tricuspid annulus Peak Systolic velocity

5. Discussion

During the last two decades, HTx has been established as a satisfactorily adequate treatment modality for patients with end-stage heart failure (2-4). With the increasing success of HTx programs, the number of long-term survivors is growing continuously (5-7). The present study was focused on a single-center experience at a follow-up period of 5 months at Masih-Daneshvari Heart Transplantation Center. Twenty consecutive HTx recipients were followed up regularly for up to 5 months, and 16 of these patients fulfilled the regular outpatient visits in our HTx clinic. In the short-term HTx survivors, acute rejection (14, 15) and infection play a dominant role in the mortality (16, 17), while the main causes of complications in the long-term survivors are chronic rejection and the side effects



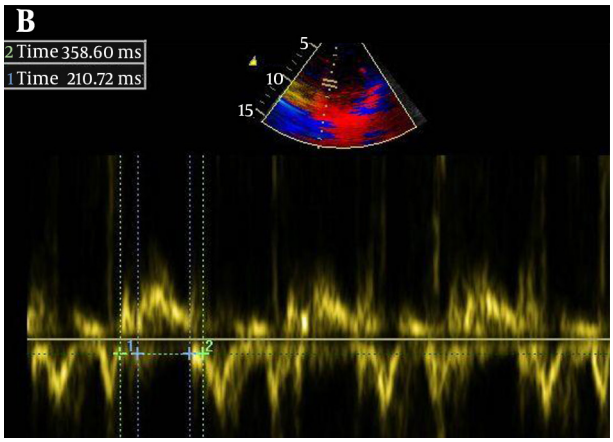


Figure 5. Upper: Early post-Heart Transplantation Myocardial Performance Index (MPI = 0.70) Lower: Myocardial Performance Index 5 Months after Heart Transplantation (MPI=0.59)

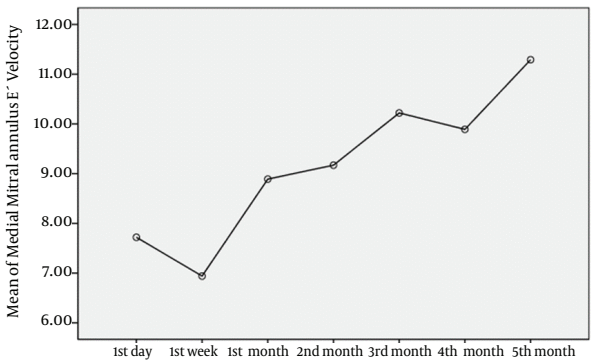


Figure 6. Diagram Showing Gradual Improvement in the Medial Mitral Annulus Early Diastolic (E`) Velocity

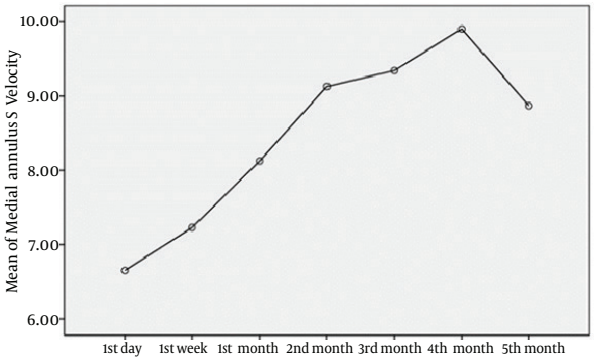


Figure 7. Diagram Showing Gradual Improvement in the Mitral Annulus Systolic (S) Velocity

of immunosuppressive medications. Moreover, reduced graft function may occur owing to the denervation of the graft and rhythm disturbances (2, 3). Consequently, echocardiographic evaluation remains mandatory for the continuously growing number of patients surviving HTx (4-7). All the HTx operations were performed via bicaval anastomosis in our center, precluding a comparison between the effects of the different techniques (bicaval vs. biatrial) on echocardiographic findings (18). One of the gravest late complications of HTx is graft-associated coronary artery vasculopathy, which is primarily observed in the first postoperative year. Our short-term follow-up of the study population showed no such complication (19, 20); nonetheless, a longer-term follow-up of our patients might have yielded a different outcome as regards this complication. As was expected, mild RV enlargement and systolic dysfunction and mild pulmonary arterial hypertension were observed in the early postoperative period, but all of them improved gradually overtime. A rise in the RV volume shortly after HTx is an adaptive mechanism to pulmonary hypertension, which is generally present in the recipients due to chronic heart failure and congested pulmonary circulation. Previous research has demonstrated a regression in such changes within a few months after HTx (21). Otherwise, elevated pulmonary vascular resistance and pulmonary hypertension could ensue the pretreatment of the organ donor, ischemic damage, and reperfusion injury in the wake of prolonged ischemia and the perioperative use of cardiopulmonary bypass (heart-lung machines), blood transfusion and protamine administration, and pulmonary vasoconstriction secondary to hypoxia, which can be modified by adjusting the setting of the ventilator and optimal positive end-expiratory pressure. The echocardiographic assessment of our study population at 5 months' follow-up revealed the following major findings:

1) All the patients had a well-preserved LV systolic function.

2) The whole study population had normal LVEDD and LVESD.

3) There was mild and nonsignificant left atrial enlargement in the majority of the patients despite the use of the bicaval anastomosis technique in all the cases. This finding is consistent with a study by Lauerma et al. (22), who performed HTx on 10 patients via the classic biatrial anastomosis technique and reported mild left atrial enlargement (3.7 ± 8.9 cm) according to cardiac magnetic resonance imaging, and also with a study by Traversi et al. (23), who compared the two anastomosis techniques in terms of the right and left atrial volumes and functions using detailed echocardiography and reported smaller atrial volume and better function in the bicaval technique.

4) There was mild RV enlargement in the majority of our patients early after HTx. This finding chimes in with a study by Hosenpud et al. (24), who performed HTx on 10 patients and reported mild RV enlargement in the first postoperative week (3.4 ± 0.6 cm) and at 3 months' follow-up (3.9 ± 0.6 cm), which was considered normal findings early after HTx.

5) There were intact left-sided heart valves as opposed to tricuspid regurgitation in the majority of the grafts: 38 %> mild tricuspid regurgitation in the early post-HTx period and 6.2 % moderate /severe grade tricuspid regurgitation at 5 months' follow-up. This finding is concordant with a study by Rees and Sivarajan (25, 26), who performed HTx on 48 patients and reported tricuspid regurgitation in 41 (trivial tricuspid regurgitation in 23, mild in 12, and moderate in only 6; other valvular lesions such as mitral and aortic regurgitation were not common), and with a study by Chan et al. (27-30), who reported that 92.2 % of their HTx recipients were free of severe tricuspid regurgitation at 5 years' follow-up.

6) There was a gradual improvement in the RV systolic function as assessed by TAPSE and TDI-derived peak S velocity during our 5-month follow-up period. This finding is in line with a study by Fyfe et al. (31), who performed HTx on 21 pediatric patients and reported some degree of RV dysfunction with reduced tricuspid systolic velocity (5.8 ± 1.4 cm/sec), which failed to normalize even 5 years after transplantation.

7) There was a gradual increase in the TD-derived velocities of the medial and lateral mitral annuli (E`, A`) during our 5-month follow-up period. This finding tallies with another study by Fyfe et al. (32), who performed HTx on 53 pediatric patients at a mean age of 10 years and reported reduced tricuspid systolic velocity (2 to 2.9 cm/sec), reduced tricuspid early diastolic velocity (1.9 to 3.7 cm/sec), and mitral systolic velocity of up to 1.5 cm/sec. The authors suggested that TDI be conducted two to three times each year to survey graft impairment because only in HTx patients with graft failure is a higher rate of reduction in velocities noticed at early follow-up.

8) There was an unchanged mean LV filling pressure as measured with the E/E` ratio.

9) There was a prolonged MPI after HTx with a nonsignificant reduction at 5 months' follow-up. Frea et al. (33) performed HTx on 152 patients and reported a higher rate of adverse cardiac events in cases with a prolonged MPI > 0.45 at a follow-up period of 5 years.

This study underscores the feasibility of echocardiography in the postoperative evaluation of HTx patients. Future studies with larger populations and loner follow-up periods are required to shed further light on the morphological changes of heart grafts and the role of echocardiography.

References

1. Kitamura S, Nakatani T, Kato T, Yanase M, Kobayashi J, Nakajima H, et al. Hemodynamic and echocardiographic evaluation of orthotopic heart transplantation with the modified bicaval anastomosis technique. *Circ J.* 2009;**73**(7):1235–9.
2. Fraund S, Pethig K, Franke U, Wahlers T, Harringer W, Cremer J, et al. Ten year survival after heart transplantation: palliative procedure or successful long term treatment? *Heart.* 1999;**82**(1):47–51.
3. Hetzer R, Albert W, Hummel M, Pasic M, Loebe M, Warnecke H, et al. Status of patients presently living 9 to 13 years after orthotopic heart transplantation. *Ann Thorac Surg.* 1997;**64**(6):1661–8.
4. Heublein B, Haverich A, Borst HG. Long-term follow-up after orthotopic heart transplantation. *Thorac Cardiovasc Surg.* 1990;**38**(5):285–90.
5. von Scheidt W, Ziegler U, Kemkes BM, Reichart B, Erdmann E. Long-term myocardial function after heart transplantation. *Thorac Cardiovasc Surg.* 1993;**41**(3):156–62.
6. DeCampli WM, Luikart H, Hunt S, Stinson EB. Characteristics of patients surviving more than ten years after cardiac transplantation. *J Thorac Cardiovasc Surg.* 1995;**109**(6):1103–14.
7. Robbins RC, Barlow CW, Oyer PE, Hunt SA, Miller JL, Reitz BA, et al. Thirty years of cardiac transplantation at Stanford university. *J Thorac Cardiovasc Surg.* 1999;**117**(5):939–51.
8. Putzer GJ, Cooper D, Keehn C, Asante-Korang A, Boucek MM, Boucek RJ. An improved echocardiographic rejection-surveillance strategy following pediatric heart transplantation. *J Heart Lung Transplant.* 2000;**19**(12):1166–74.
9. Sade LE, Sezgin A, Ulucam M, Taymaz S, Simsek V, Tayfun E, et al. Evaluation of the potential role of echocardiography in the detection of allograft rejection in heart transplant recipients. *Transplant Proc.* 2006;**38**(2):636–8.
10. Thorn EM, de Filippi CR. Echocardiography in the cardiac transplant recipient. *Heart Fail Clin.* 2007;**3**(1):51–67.
11. Costanzo MR, Dipchand A, Starling R, Anderson A, Chan M, Desai S, et al. The International Society of Heart and Lung Transplantation Guidelines for the care of heart transplant recipients. *J Heart Lung Transplant.* 2010;**29**(8):914–56.
12. Spes CH, Tammen AR, Fraser AG, Uberfuhr P, Theisen K, Angermann CE. Doppler analysis of pulmonary venous flow profiles in orthotopic heart transplant recipients: a comparison with mitral flow profiles and atrial function. *Z Kardiol.* 1996;**85**(10):753–60.
13. Leonard GJ, Fricker FJ, Pruett D, Harker K, Williams B, Schowengerdt KJ. Increased myocardial performance index correlates with biopsy-proven rejection in pediatric heart transplant recipients. *J Heart Lung Transplant.* 2006;**25**(1):61–6.
14. Sun JP, Abdalla IA, Asher CR, Greenberg NL, Popovic ZB, Taylor DO, et al. Non-invasive evaluation of orthotopic heart transplant rejection by echocardiography. *J Heart Lung Transplant.* 2005;**24**(2):160–5.
15. Mondillo S, Maccherini M, Galderisi M. Usefulness and limitations of transthoracic echocardiography in heart transplantation recipients. *Cardiovasc Ultrasound.* 2008;**6**:2.
16. Puleo JA, Aranda JM, Weston MW, Cintron G, French M, Clark L, et al. Noninvasive detection of allograft rejection in heart transplant recipients by use of Doppler tissue imaging. *J Heart Lung Transplant.* 1998;**17**(2):176–84.
17. Ciliberto GR, Mascarello M, Gronda E, Bonacina E, Anjos MC, Danzi G, et al. Acute rejection after heart transplantation:

noninvasive echocardiographic evaluation. *J Am Coll Cardiol.* 1994;**23**(5):1156–61.
18. Sun JP, Niu J, Banbury MK, Zhou L, Taylor DO, Starling RC, et al. Influence of different implantation techniques on long-term survival after orthotopic heart transplantation: an echocardiographic study. *J Heart Lung Transplant.* 2007;**26**(12):1243–8.
19. Secotaro C. Usefulness of Echocardiography in Cardiac Transplant Patients. *Rev Fed Arg Cadiol.* 2014;**43**(1):6–13.
20. Nakatani T. Registry report of Japanese Society for heart transplantation. *Jpn J Transplant.* 2008;**43**:470–3.
21. Bech-Hanssen O, Al-Habeeb W, Ahmed W, Di Salvo G, Pergola V, Al-Admawi M, et al. Echocardiography Detects Elevated Left Ventricular Filling Pressures in Heart Transplant Recipients. *Echocardiography.* 2014.
22. Lauerma K, Harjula A, Jarvinen V, Kupari M, Keto P. Assessment of right and left atrial function in patients with transplanted hearts with the use of magnetic resonance imaging. *J Heart Lung Transplant.* 1996;**15**(4):360–7.
23. Traversi E, Pozzoli M, Grande A, Forni G, Assandri J, Vigano M, et al. The bicaval anastomosis technique for orthotopic heart transplantation yields better atrial function than the standard technique: an echocardiographic automatic boundary detection study. *J Heart Lung Transplant.* 1998;**17**(11):1065–74.
24. Hosenpud JD, Norman DJ, Cobanoglu MA, Floten HS, Conner RM, Starr A. Serial echocardiographic findings early after heart transplantation: evidence for reversible right ventricular dysfunction and myocardial edema. *J Heart Transplant.* 1987;**6**(6):343–7.
25. Rees AP, Milani RV, Lavie CJ, Smart FW, Ventura HO. Valvular regurgitation and right-sided cardiac pressures in heart transplant recipients by complete Doppler and color flow evaluation. *Chest.* 1993;**104**(1):82–7.
26. Sivarajan VB, Chrisant MR, Ittenbach RF, Clark B3, Hanna BD, Paridon SM, et al. Prevalence and risk factors for tricuspid valve regurgitation after pediatric heart transplantation. *J Heart Lung Transplant.* 2008;**27**(5):494–500.
27. Chan MC, Giannetti N, Kato T, Kornbluth M, Oyer P, Valantine HA, et al. Severe tricuspid regurgitation after heart transplantation. *J Heart Lung Transplant.* 2001;**20**(7):709–17.
28. Haverich A, Albes JM, Fahrenkamp G, Schafers HJ, Wahlers T, Heublein B. Intraoperative echocardiography to detect and prevent tricuspid valve regurgitation after heart transplantation. *Eur J Cardiothorac Surg.* 1991;**5**(1):41–5.
29. Yankah AC, Musci M, Weng Y, Loebe M, Zurbruegg HR, Siniawski H, et al. Tricuspid valve dysfunction and surgery after orthotopic cardiac transplantation. *Eur J Cardiothorac Surg.* 2000;**17**(4):343–8.
30. Williams MJ, Lee MY, DiSalvo TG, Dec GW, Picard MH, Palacios IF, et al. Biopsy-induced flail tricuspid leaflet and tricuspid regurgitation following orthotopic cardiac transplantation. *Am J Cardiol.* 1996;**77**(15):1339–44.
31. Fyfe DA, Mahle WT, Kanter KR, Wu G, Vincent RN, Ketchum DL. Reduction of tricuspid annular doppler tissue velocities in pediatric heart transplant patients. *J Heart Lung Transplant.* 2003;**22**(5):553–9.
32. Fyfe DA, Ketchum D, Lewis R, Sabatier J, Kanter K, Mahle W, et al. Tissue Doppler imaging detects severely abnormal myocardial velocities that identify children with pre-terminal cardiac graft failure after heart transplantation. *J Heart Lung Transplant.* 2006;**25**(5):510–7.
33. Frea S, Capriolo M, Bergamasco L, Iacovino C, Quaglia FC, Ribezzo M, et al. Prognostic role of myocardial performance index on long-term survival after heart transplantation: a prospective study. *Echocardiography.* 2013;**30**(9):1033–41.