Kardiologia Polska 2012; 70, 8: 769–773 ISSN 0022–9032

ORIGINAL ARTICLE

Does the method of heart transplantation affect left ventricular filling?

Ewa Markowicz-Pawlus[1], Agata Duszańska[1], Roman Przybylski[2], Mariola Szulik[1], Witold Streb[1], Marian Zembala[2], Zbigniew Kalarus[1], Tomasz Kukulski[1]

[1]Department of Cardiology, Congenital Heart Disease and Electrotherapy, Teaching Ward of Cardiology, Silesian Medical University, Silesian Centre for Heart Diseases, Zabrze, Poland

[2]Department and Teaching Ward of Cardiac Surgery and Transplantation Medicine, Silesian Medical University, Silesian Centre for Heart Diseases, Zabrze, Poland

Abstract

Background: For over 40 years now orthotopic heart transplantation (OHT) has been the treatment of choice in patients with advanced heart failure. For many years patients undergoing OHT have been treated with the classical approach involving anastomosis of the donor atria with the recipient atria resulting in a heart in which the atria are enlarged. An alternative method for OHT is the bicaval anastomosis technique, which involves connecting both of the donor's venae cavae with the recipient's venae cavae.

Aim: To assess left ventricular (LV) filling in patients undergoing OHT using the classical (biatrial) versus bicaval approach.

Methods: We analysed 60 patients who had undergone OHT between 1 and 36 months before. Myocardial biopsy at echocardiography revealed grade 0 or 1A rejection in all the patients. All the patients were also in NYHA functional class I. The patients were divided in two groups: patients who had undergone biatrial anastomosis (Group 1, n = 40) and patients who had undergone bicaval OHT (Group 2, n = 20). In order to render the results independent of pre-OHT blood pressure values in the pulmonary circulation we assessed the values of right ventricular systolic pressure (RVSP), mean pulmonary artery pressure (PAP) and transpulmonary gradient (TPG) in all the patients before OHT. We assessed the following echocardiographic parameters: peak early filling velocity (E-wave), peak atrial filling velocity (A-wave), E-wave deceleration time, early diastolic mitral valve ring motion velocity (E′), E/E′, isovolumetric relaxation time of the LV, duration of the A-wave, right atrial area and left atrial area, LV mass, LV mass index, LV end-diastolic and end-systolic dimension, and the severity of tricuspid regurgitation (TR).

Results: The values of RVSP, PAP and TPG in the study groups before OHT did not differ significantly. The values of E (86.5 ± 12.5 vs. 67.3 ± 8.5; $p < 0.001$), E′ (11.9 ± 1.1 vs. 10.9 ± 0.9; $p = 0.003$) and E/E′ (7.4 ± 1.5 vs. 6.1 ± 0.85; $p = 0.006$) differed between the groups and were significantly higher in the group undergoing surgery using the biatrial approach. The duration of the A-wave was significantly longer in the group undergoing surgery using the bicaval approach (129.0 ± 5.1 vs. 136.7 ± 10.0; $p = 0.001$). There were no significant differences in the other parameters of LV filling. Right atrial area was significantly lower in the group undergoing surgery using the bicaval approach (19.2 ± 3.0 vs. 14.0 ± 2.0; $p < 0.001$). LV size, LV mass and LV mass index did not differ significantly between the groups. The lack of TR was more commonly observed in the group undergoing surgery using the bicaval approach at the limit of $p = 0.05$. Pacemaker implantation was required in 12 (30%) patients from the group undergoing surgery using the classical method and 2 (10%) patients from the group undergoing OHT using the bicaval approach ($p = 0.04$).

Conclusions: Certain echocardiographic parameters suggest a better LV filling in patients undergoing OHT using the bicaval approach. Preservation of the right atrial geometry in patients undergoing OHT using the bicaval approach plays an important role in LV filling.

Key words: left ventricle, filling, heart transplantation, bicaval

Kardiol Pol 2012; 70, 8: 769–773

Address for correspondence:
Ewa Markowicz-Pawlus, MD, Silesian Centre for Heart Diseases, ul. Skłodowskiej 9, 41-800 Zabrze, Poland, e-mail: markowicz_e@yahoo.com
Received: 04.09.2011 **Accepted:** 11.01.2012

INTRODUCTION

For over 40 years now orthotopic heart transplantation (OHT) has been the treatment of choice in patients with advanced heart failure. For many years patients undergoing OHT have been treated with the classical (biatrial) approach described by Richard Lower and Norman Schumway [1]. The biatrial approach involves anastomosis of the donor atria with the recipient atria resulting in a heart in which the atria are enlarged [2].

The simplicity of the technique and the short duration of ischaemia are two unquestionable advantages of this method. An alternative method for OHT is the bicaval anastomosis technique, which involves connecting both of the donor's venae cavae with the recipient's venae cavae. In the recipient, both venae cavae are cannulated and after the heart has been removed from the chest, access to the recipient's atria is gained. After the venae cavae are cut off, the remaining portion of the left atrium (LA) is resected and only the posterior part with the pulmonary vein ostia is left behind. The anastomosis includes the LA, aorta, pulmonary artery and the venae cavae. This way the function of the right atrium (RA), sinoatrial node and the tricuspid valve is preserved [3, 4].

Impaired left ventricular (LV) filling may deteriorate exercise capacity of patients who have undergone OHT, particularly since this group of patients is characterised by accelerated heart rate.

The aim of the study was to assess LV filling in patients undergoing OHT using the classical versus bicaval approach.

METHODS

We analysed 60 patients who had undergone OHT between 1 and 36 months before. Myocardial biopsy at echocardiography revealed grade 0 or 1A rejection in all the patients. All the patients were also in NYHA functional class I.

The patients were divided in two groups: patients who had undergone biatrial anastomosis (Group 1, n = 40) and patients who had undergone bicaval OHT (Group 2, n = 20). Atrial sizes, LV size and LV mass were calculated in the parasternal transverse and four-chamber (4CH) views. LV filling parameters were assessed during routine echocardiography in the 4CH view and using pulsed-wave Doppler and tissue Doppler imaging in accordance with the current standards [5, 6].

We assessed the following echocardiographic parameters: peak early filling velocity (E-wave [cm/s]), peak atrial filling velocity (A-wave [cm/s]), E-wave deceleration time (DT [ms]) (time from the peak of the E-wave until its disappearance), peak early diastolic mitral valve ring motion velocity (E′) measured in the basolateral segment, E/E′, isovolumetric relaxation time of the LV, duration of the A-wave. We also assessed RA area (RAA), LA area (LAA), LV mass and LV mass per square meter of body surface area (LV mass index), LV end-diastolic dimension and LV end-systolic dimension.

Tricuspid regurgitation (TR) was assessed during routine echocardiography in the 4CH view; TR was rated as absent, mild or moderate. We did not observe cases of severe TR in our analysis. The only cases of mitral regurgitation we observed were mild.

In order to render the results independent of pre-OHT blood pressure values in the pulmonary circulation we assessed the values of right ventricular systolic pressure (RVSP), mean pulmonary artery pressure (PAP) and transpulmonary gradient (TPG) in all the patients before OHT.

Statistical analysis

Values calculated for measureable variables were expressed as arithmetic means and standard deviations. For normally distributed data, the comparative analysis of the means was performed using the t-Student test. The χ^2 test was used to compare the distribution of risk factors between the groups.

RESULTS

The values of RVSP, PAP and TPG in the study groups before OHT did not differ significantly (Table 1). Based on that a further echocardiographic analysis was performed, as the potential differences in the values of the parameters defining the pressures and resistances in the pulmonary circulation before OHT, through their influence on preload, could confound the analysis of LV filling in individual patients.

The values of the echocardiographic parameters are summarised in Tables 2 and 3.

The values of E, E′ and E/E′ differed between the groups and were significantly higher in the group undergoing surgery using the biatrial approach. The duration of the A-wave was significantly longer in the group undergoing surgery using the bicaval approach. There were no significant differences in the other parameters of LV filling. RAA was significantly lower in the group undergoing surgery using the bicaval approach. LV size, LV mass and LV mass index did not differ significantly between the groups.

Table 1. The values of echocardiographic and haemodynamic parameters before orthotopic heart transplantation (OHT)

	Biatrial OHT	Bicaval OHT	P
Right ventricular systolic pressure [mm Hg]	41.9 ± 10.7	37 ± 6.0	NS
Mean pulmonary artery pressure [mm Hg]	28.0 ± 9.6	32.9 ± 9.0	NS
Transpulmonary gradient [mm Hg]	10.5 ± 5.0	8.5 ± 4.2	NS

Table 2. Values of the echocardiographic parameters used to assess left ventricular filling

	E [cm/s]	E' [cm/s]	E/E'	DT [ms]	A [cm/s]	IVRT [ms]	E/A	A dur. [ms]
Biatrial OHT	86.5 ±12.5	11.9 ± 1.1	7.4 ± 1.5	156.0 ± 6.1	50.1 ± 8.5	71.9 ± 2.96	1.72	129.0 ± 5.1
Bicaval OHT	67.3 ± 8.5	10.9 ± 0.9	6.1 ± 0.85	155.3 ± 4.1	37.3 ± 4.0	72.6 ± 2.1	1.81	136.7 ± 10.0
P	< 0.001	0.003	0.006	NS	NS	NS	NS	0.001

OHT — orthotopic heart transplantation; E — peak early filling velocity; E' — early diastolic mitral valve ring motion velocity; A — peak atrial filling velocity; DT — E-wave deceleration time; IVRT — isovolumetric relaxation time of the left ventricle; A dur. — duration of the A-wave

Table 3. Values of the remaining echocardiographic parameters used to assess left ventricular diastolic function

	LVM [g]	LVMI [g/m²]	LVEDD [mm]	LVESD[mm]	RAA [cm²]	LAA [cm²]
Biatrial OHT	151.7 ± 16.4	84.3 ± 8.8	53.2 ± 3.5	34.0 ± 2.1	19.2 ± 3.0	22.0 ± 3.1
Bicaval OHT	145.2 ± 17.0	81.6 ± 6.0	52.1 ± 2.3	32.7 ± 2.5	14.0 ± 2.0	20.6 ± 2.3
P	NS	NS	NS	NS	< 0.001	0.07

OHT — orthotopic heart transplantation; LVM — left ventricular mass; LVMI — LVM index; LVEDD — left ventricular end diastolic dimension; LVESD — left ventricular end systolic dimension; RAA — right atrial area; LAA — left atrial area

Table 4. Severity of tricuspid regurgitation (TR)

	No TR	Mild TR	Moderate TR
Biatrial OHT	29 (72%)	7 (18%)	5 (12.5%)
Bicaval OHT	18 (90%)	2 (10%)	0
P	0.05	NS	

OHT — orthotopic heart transplantation

Table 4 compares TR severities between the groups. There were no significant differences in the incidence of mild TR between the groups, although the lack of TR was more commonly observed in the group undergoing surgery using the bicaval approach at the statistical significance limit of $p = = 0.05$. No cases of moderate TR were observed in the group undergoing surgery using the bicaval approach. Pacemaker implantation was required in 12 (30%) patients from the group undergoing surgery using the classical method and 2 (10%) patients from the group undergoing OHT using the bicaval approach ($p = 0.04$).

DISCUSSION

The bicaval approach to OHT was introduced, as an alternative to the classical OHT technique, on the assumption that this method would preserve the function of the atria, tricuspid valve and the sinoatrial node.

Reports confirm a lower incidence of TR and a less frequent necessity for pacemaker implantation in patients undergoing OHT using the bicaval approach [1, 3, 4, 7–15]. Also in our analysis, pacemaker implantation was required significantly more commonly in the group undergoing surgery using the classical approach.

We also analysed tricuspid valve function. Generally, mild TR does not lead to haemodynamic abnormalities, while significant TR may lead to right ventricular failure of the heart graft and affects early and late mortality following OHT. There are reports postulating the impact of graft rejection on TR, while all the patients in the study population had grade 0 or 1A rejection. The most likely theory explaining the association of TR with the surgical technique in OHT involves distorted geometry of the recipient's RA through its connection with the donor's atrium. This is avoided by using the bicaval method.

In our analysis, the lack of TR was more commonly observed in the group undergoing surgery using the bicaval approach at the statistical significance limit of $p = 0.05$. There were no significant differences in the incidence of mild TR between the groups.

Due to the lower volume and the shape of the RA its emptying and right ventricular filling are not impaired in patients undergoing surgery using the bicaval approach compared to those undergoing surgery using the biatrial approach, who have a tendency towards blood congestion in the RA. There are few reports assessing LV filling in patients following OHT performed using various methods [16].

In order to render the results independent of pre-OHT blood pressure values in the pulmonary circulation we assessed the values of RVSP, PAP and TPG in all the patients before OHT and found no significant differences between the groups.

In addition, in order to avoid the impact of LV myocardial thickness on LV filling we assessed LV mass in both groups, revealing no significant differences between the groups. Also the diastolic and systolic LV dimensions were similar in the study groups.

We showed a significantly higher LV early filling velocities (E-waves) in patients undergoing surgery using the classical approach compared to those undergoing surgery using the bicaval approach, which may suggest an increased LV filling pressure in patients from the former group, given the similar LA dimensions in both groups.

The duration of atrial systole during mitral inflow was significantly longer in patients undergoing surgery using the bicaval approach than in patients undergoing surgery using the classical approach, which — given the lower velocity of the A-wave — indicates a higher LV compliance. The remaining parameters of the diastolic function of the LV were normal and similar in both groups.

Early diastolic mitral valve ring motion velocity (E′-wave) was significantly lower in the group of patients undergoing surgery using the bicaval approach. It is believed that the higher the E′ value, the better the systolic function of the myocardium. In this case, E′ values in both groups were normal and significantly higher in the group of patients undergoing surgery using the classical approach. All the patients in the study population had normal LV ejection fraction at the time of echocardiography.

In the group of patients undergoing surgery using the bicaval approach, the E/E′ value was significantly lower than that in the group of patients undergoing surgery using the classical approach. E/E′ is a simple, non-invasive test which allows us to estimate LV filling pressure. Therefore, the above finding suggests a lower LV filling pressure in patients undergoing surgery using the bicaval approach. In line with the assumptions of the method, RA dimension was significantly lower in patients undergoing surgery using the bicaval approach than in patients undergoing surgery using the classical approach, which is associated with the method of anastomosis.

LA size was lower in the group of patients undergoing surgery using the bicaval approach, although the difference was statistically non-significant ($p = 0.07$).

In our opinion, the above finding is associated with the fact that when using the classical method the new LA is created by anastomosis of the donor's LA and the recipient's LA, while in the bicaval method, the atrium is cut off at the pulmonary vein ostia in contrast to total OHT, where the recipient's pulmonary veins are anastomosed with the donor's LA.

In addition, some authors have shown a lower incidence of atrial flutter, which arises in the RA isthmus in patients undergoing surgery using the bicaval approach [17].

At present, the bicaval approach is a commonly used method of OHT. Although it often less advantageous than the total OHT technique, it represents without a doubt considerable progress in the surgical techniques used in patients undergoing OHT.

CONCLUSIONS

Certain echocardiographic parameters suggest a better LV filling in patients undergoing OHT using the bicaval approach. Preservation of the RA geometry in patients undergoing OHT using the bicaval approach plays an important role in LV filling.

Conflict of interest: *none declared*

References

1. Shumway NE, Lower R, Stofer RC. Transplantation of the heart. Adv Surg, 1966; 2: 265–284.
2. Przybylski R, Zembala M, Maruszewski M et al. Orthotopic heart transplantations with application of bicaval anastomosis technique-why to improve classical transplantation method. Kardiochir Torakochir Pol, 2005; 2: 105–109.
3. Jacob S, Sellke F. Is bicaval orthotopic heart transplantation superior to the biatrial technique? Interact Cardiovasc Thorac Surg, 2009; 9: 333–342.
4. Magliato KE, Trento A. Heart transplantation-surgical results. Heart Fail Rev, 2001; 6: 213–219.
5. Nagueh SF, Appleton CP, Gillebert TC et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. Eur J Echocardiogr, 2009; 10: 165–193.
6. Paulus WJ, Tschöpe C, Sanderson JE et al. How to diagnose diastolic heart failure: a consensus statement on the diagnosis of the heart failure with normal left ventricular ejection fraction by the Heart Failure and Echocardiography Associations of the European Society of Cardiology. Eur Heart J, 2007; 28: 2539–2550.
7. Sievers HH, Leyh R, Jahnke A et al. Bicaval versus atrial anastomoses in cardiac transplantation. Right atrial dimension and tricuspid valve function at rest and during exercise up to thirty-six months after transplantation. J Thorac Cardiovasc Surg, 1994; 108: 780–784.
8. Kitamura S, Nakatani T, Kato T et al. Hemodynamic and echocardiographic evaluation of orthotopic heart transplantation with the modified bicaval anastomosis technique. Circ J, 2009; 73: 1235–1239.
9. Morgan JA, Edwards NM. Orthotopic cardiac transplantation: comparison of outcome using biatrial, bicaval and total techniques. J Card Surg, 2005; 20: 102–106.
10. Sun JP, Niu J, Banbury MK et al. Influence of different implantation techniques on long-term survival after orthotopic heart transplantation: an echocardiographic study. J Heart Lung Transplant, 2007; 26: 1243–1248.
11. Locali RF, Matsuoka PK, Cherbo T et al. Should biatrial heart transplantation still be performed? A meta-analysis. Arq Bras Cardiol, 2010; 94: 829–840.
12. Marelli D, Silvestry SC, Zwas D et al. Modified interior vena caval anastomosis to reduce tricuspid valve regurgitation after transplantation. Tex Heart Inst J, 2007; 34: 30–35.
13. Solomon NA, McGiven J, Chen XZ et al. Biatrial or bicaval technique for orthotopic heart transplantation: which is better? Heart Lung Circ, 2004; 13: 389–394.
14. Schnoor M, Schäfer T, Lühmann D et al. Bicaval versus standard technique In orthotopic heart transplantation: a systematic review and meta-analysis. J Thorac Cardiovasc Surg, 2007; 134: 1322–1331.
15. Park KY, Park CH, Chun YB et al. Bicaval anastomosis reduces tricuspid regurgitation after heart transplantation. Asian Cardiovasc Thorac Ann, 2005; 13: 251–254.
16. Bittner HB, Chen EP, Kendall SW et al. Total atrioventricular cardiac transplantation preserves atrial systole and ventricular diastolic filling. Ann Thorac Surg, 1997; 63: 814–821.
17. Grant SC, Khan MA, Faragher EB et al. Atrial arrhythmias and pacing after orthotopic heart transplantation: bicaval versus standard atrial anastomosis. Br Heart J, 1995; 74: 149–153.

Czy metoda transplantacji serca wpływa na napełnianie lewej komory?

Ewa Markowicz-Pawlus[1], Agata Duszańska[1], Roman Przybylski[2], Mariola Szulik[1], Witold Streb[1], Marian Zembala[2], Zbigniew Kalarus[1], Tomasz Kukulski[1]

[1]Katedra Kardiologii, Wrodzonych Wad Serca i Elektroterapii, Oddział Kliniczny Kardiologii, Śląski Uniwersytet Medyczny, Śląskie Centrum Chorób Serca, Zabrze

[2]Katedra i Oddział Kliniczny Kardiochirurgii i Transplantologii, Śląski Uniwersytet Medyczny, Śląskie Centrum Chorób Serca, Zabrze

Streszczenie

Wstęp: Od ponad 40 lat transplantacja serca (OHT) jest leczeniem z wyboru chorych z zaawansowaną niewydolnością serca. Przez wiele lat pacjenci poddani OHT byli operowani metodą klasyczną, która polega na zespoleniu obu przedsionków dawcy z przedsionkami biorcy, w związku z czym u biorcy funkcjonuje serce, którego przedsionki są powiększone. Alternatywną metodą OHT jest zespolenie bikawalne, czyli łączenie obu żył głównych dawcy z żyłami głównym biorcy.

Cel: Celem pracy była ocena napełniania lewej komory (LV) chorych po OHT operowanych metodą klasyczną (biatrialną) i bikawalną.

Metody: Analizą objęto 60 pacjentów przez 1–36 miesięcy po OHT. Wszyscy chorzy charakteryzowali się 0 lub 1A stopniem odrzutu w biopsji miokardialnej w momencie badania echokardiograficznego i byli w I klasie wg NYHA. Pacjentów podzielono na 2 grupy: 40 chorych po zespoleniu biatrialnym (grupa I) i 20 chorych po bikawalnym OHT (grupa II). Aby uniezależnić wyniki od wartości ciśnienia w krążeniu płucnym przed OHT, zbadano wartości skurczowego ciśnienia w prawej komorze (RVSP), średniego ciśnienia w tętnicy płucnej (PAP) i gradientu przezpłucnego (TPG) u wszystkich badanych przed OHT. Ocenie poddano parametry echokardiograficzne: maksymalną prędkość fali wczesnego napływu — fala E, maksymalną prędkość napływu przedsionkowego — fala A, czas deceleracji fali E, maksymalną prędkość wczesnorozkurczowego ruchu pierścienia mitralnego (E'), E/E', czas izowolumetrycznego rozkurczu LV, czas trwania fali A, pole powierzchni prawego i lewego przedsionka, masę LV (LVM), wskaźnik LVM, wymiar końcoworozkurczowy i końcowoskurczowy LV oraz wielkość niedomykalności trójdzielnej (TR).

Wyniki: Wartości RVSP, PAP i TPG w badanych grupach przed OHT nie różniły się istotnie. Wartości E (86,5 ± 12,5 *v.* 67,3 ± ± 8,5; $p < 0,001$), E' (11,9 ± 1,1 *v.* 10,9 ± 0,9; $p = 0,003$) i E/E' (7,4 ± 1,5 v. 6,1 ± 0,85; $p = 0,006$) różniły się między obiema grupami i były istotnie większe w grupie operowanej metodą biatrialną. Czas trwania fali A był istotnie dłuższy w grupie operowanej metodą bikawalną (129,0 ± 5,1 *v.* 136,7 ± 10,0; $p = 0,001$). Nie zaobserwowano istotnych różnic dla innych parametrów obrazujących napełnianie LV. Pole powierzchni prawego przedsionka było istotnie mniejsze w grupie operowanej metodą bikawalną (19,2 ± 3,0 *v.* 14,0 ± 2,0; $p < 0,001$). Wielkość LV, LVM i LVMI nie różniły się istotnie między obiema grupami. Brak TR obserwowano częściej w grupie operowanej metodą bikawalną, przy granicznym poziomie $p = 0,05$. Konieczność implantacji rozrusznika serca wystąpiła u 12 (30%) chorych z grupy operowanej klasycznie i u 2 (10%) pacjentów z grupy poddanej bikawalnej OHT ($p = 0,04$).

Wnioski: Niektóre parametry echokardiograficzne wskazują na lepsze napełnianie LV u chorych poddanych bikawalnej metodzie OHT. Zachowanie geometrii prawego przedsionka u chorych poddanych bikawalnej metodzie OHT odgrywa ważną rolę w napełnianiu LV.

Słowa kluczowe: lewa komora, napełnianie, transplantacja serca, bikawalna

Kardiol Pol 2012; 70, 8: 769–773

Adres do korespondencji:
lek. Ewa Markowicz-Pawlus, Śląskie Centrum Chorób Serca, ul. Skłodowskiej 9, 41–800 Zabrze, e-mail: markowicz_e@yahoo.com
Praca wpłynęła: 04.09.2011 r. **Zaakceptowana do druku:** 11.01.2012 r.