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Original Article / Özgün Makale

Effects of atrial septal defect transcatheter closure on parameters of right ventricular functions

Atriyal septal defektlerin transkateter yolla kapatılmasının sağ ventrikül fonksiyonel parametreleri üzerine etkileri

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ABSTRACT

Background: This study aims to investigate the early period effects of transcatheter closure of atrial septal defects on systolic and diastolic right ventricular functions.

Methods: Forty-six patients with secundum atrial septal defects (22 males, 24 females; mean age 102.9±20 months; range 61 to 178 months) (study group) who were suitable for and who underwent successful transcatheter closure and 35 healthy, age and body mass index-matched children (17 males, 18 females; mean age 104.2±21 months; range 60 to 180 months) (control group) were evaluated prospectively. Echocardiographic examination was performed before and 24 hours and one month after the transcatheter closure procedure and results of the two groups were compared.

Results: For transcatheter closure, Lifetech Ceraflex™ was used in 44 patients and Nit-occlud PFM was used in two patients. Mean tricuspid valve annular plane systolic excursion values of study group before and one day and one month after the closure were 17.5±1.9 mm, 19.1±2.6 mm, and 20.2±2.4 mm, respectively. Mean tricuspid valve annular plane systolic excursion value of control group was 20.4±2.3 mm. In both groups, there was no significant difference between the mean tricuspid valve annular plane systolic excursion values obtained one day and one month after the closure (p>0.05). Mean tricuspid valve annular plane systolic excursion values before the closure were significantly lower than those of the first day and first month after the procedure. There was no significant difference in the mean myocardial performance index values between the study and control groups one month after the procedure. (p>0.05).

Conclusion: Compared to control group, high myocardial performance index and low tricuspid valve annular plane systolic excursion values in study group before transcatheter closure indicate low right ventricular function. Low myocardial performance index and high tricuspid valve annular plane systolic excursion values after closure suggest that transcatheter closure of atrial septal defects improve right ventricular functions even in early period.

Keywords: Atrial septal defect; echocardiography; right ventricular function.

ÖZ

Amaç: Bu çalışmada atriyal septal defektlerin transkateter yolla kapatılmasının sistolik ve diyastolik sağ ventrikül fonksiyonları üzerindeki erken dönem etkileri araştırıldı.

Çalışma planı: Transkateter kapatma için uygun olan ve başarıyla uygulanan sekundum atriyal septal defektli 46 hasta (22 erkek, 24 kız; ort. yaş 102.9±20 ay; dağılım 61-178 ay) (çalışma grubu) ve 35 sağlıklı, yaş ve vücut kütle indeksi eşleştirilmiş çocuk (17 erkek, 18 kız; ort. yaş 104.2±21 ay; dağılım 60-180 ay) (kontrol grubu) prospektif olarak değerlendirildi. Transkateter kapatma işleminden önce ve işlemden 24 saat ve bir ay sonra ekokardiyografik inceleme yapıldı ve iki grubun sonuçları karşılaştırıldı.

Bulgular: Transkateter kapatma için 44 hastada Lifetech Ceraflex™, iki hastada Nit-occlud PFM kullanıldı. Kapatmadan önce, kapatmadan bir gün ve bir ay sonra çalışma grubunun ortalama triküspit anüler düzlem sistolik hareketi değerleri sırasıyla 17.5±1.9 mm, 19.1±2.6 mm ve 20.2±2.4 mm idi. Kontrol grubunun ortalama triküspit anüler düzlem sistolik hareketi değeri 20.4±2.3 mm idi. Her iki grupta kapatma işleminden bir gün ve bir ay sonra edinilen ortalama triküspit anüler düzlem sistolik hareketi değerleri arasında anlamlı farklılık yoktu (p>0.05). Kapatmadan önceki ortalama triküspit anüler düzlem sistolik hareketi değerleri işlem sonrası birinci gün ve birinci aya göre anlamlı olarak daha düşük idi. Çalışma ve kontrol grupları arasında işlemden bir ay sonraki ortalama miyokardiyal performans indeksi değerleri açısından anlamlı bir fark yoktu. (p>0.05).

Sonuç: Kontrol grubu ile karşılaştırıldığında, çalışma grubunda transkateter kapatma öncesi yüksek miyokardiyal performans indeksi ve düşük triküspit anüler düzlem sistolik hareketi değerleri düşük sağ ventrikül fonksiyonuna işaret etmektedir. Kapatma sonrası düşük miyokardiyal performans indeksi ve yüksek triküspit anüler düzlem sistolik hareketi değerleri atriyal septal defektlerin transkateter yolla kapatılmasının erken dönemde bile sağ ventrikül fonksiyonlarını iyileştirdiğini düşündürmektedir.

Anahtar sözcükler: Atriyal septal defekt; ekokardiyografi; sağ ventrikül fonksiyonu.

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Atrial septal defect (ASD) is one of the most commonly recognized congenital cardiac diseases. It is an important cause of mortality and morbidity in adults as well as children. It is debatable whether the transcatheter closure of ASDs affects right ventricular (RV) function.[1,2] There are a great number of studies showing that RV functions are preserved after transcatheter closure of ASDs.[1] During the last decade, there has been a remarkable change in the treatment strategy of ASDs, shifting the therapeutic gold standard from surgery to transcatheter closure. There are different kinds of devices for transcatheter ASD closure. The Ceraflex ASD occluder consists of nitinol wire frame without a left atrial hub covered by a polyethylene terephthalate membrane that minimizes the chance of clot formation and increases flexibility. The Nit-Occlud® PFM consists of two discs, a distal or left one and a proximal or right one. Studies show that acute RV failure after ASD surgery continues to be a significant problem.[3]

Right ventricular ejection fraction (RVEF) is difficult to assess both with accuracy and ease. This is due to the complex geometrical shape of the RV rendering volume measurements by echocardiography prone to error and awkward and because the more precise respective determinations by the reference method, i.e. magnetic resonance imaging (MRI), are not readily available and costly.[4,5] Studies show that tricuspid valve annular plane systolic excursion (TAPSE) and myocardial performance index (MPI or Tei index, MPI-Tei index) measurements reflect the RVEF results obtained by MRI.[4-6]

Right ventricular function assessment can be performed by TAPSE with M-mode echocardiography, isovolumic contraction time (ICT), isovolumic relaxation time (IRT), and ejection time (ET) by tissue Doppler imaging and MPI-TEI index.

Tissue Doppler imaging assesses RV function independent of preload and afterload.[7] Myocardial performance index (MPI), first described by Tei[8] and Tei et al.,[9] is a Doppler-derived time interval index that combines both systolic and diastolic cardiac performance. MPI is calculated by dividing the sum of ICT and IRT to ET from the Doppler trace. Right ventricular EF as determined by MRI correlated significantly with respective values as assessed by TAPSE and MPI.[4-6] Therefore, in this study, we aimed to investigate the early period effects of transcatheter closure of ASDs on systolic and diastolic RV functions.

PATIENTS AND METHODS

This prospective study included a total of 81 individuals who were referred to Department of Pediatric Cardiology of Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital for functional murmurs between May 2013 and June 2015. Of these, 46 with secundum ASD (22 males, 24 females; mean age 102.9±20 months; range 61 to 178 months) underwent transcatheter closure of ASDs (study group) and 35 were healthy, age and body mass index-matched children (17 males, 18 females; mean age 104.2±2 months; range 60 to 180 months) (control group). Demographic features of study and control groups are summarized in Table 1. The study protocol was approved by our institutional ethics committee for human objects. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patients had no cardiovascular disease other than ASD, while each subject in control group underwent a complete echocardiographic assessment by a pediatric cardiologist and was deemed to have normal cardiac status.

Left ventricular systolic and diastolic functions of the patients were normal before and after the procedure. Arrhythmias were not encountered before or after the procedure in the study group. Study group patients did not have congestive heart failure before the procedure. Lifetech Ceraflex™ device was used for the

Table 1. Demographic features of study and control groups

	Control group (n=35)		Study group (n=46)		
	n	Mean±SD	n	Mean±SD	*p*
Age (month)		104.2±21.2		102.9±24.0	>0.05
Heart rate (minute)		78±1.6		79±1.8	>0.05
Gender					>0.05
Male	17		22		
Female	18		24		
Body mass index		17.4±2.7		17.3±2.5	>0.05

SD: Standard deviation.

ASD closure of 44 patients whereas Nit-Occlud® PFM were used for the other two patients. There were no residual defects after the ASD closure procedure.

Echocardiography was performed for the patients at their time of admission as well as one day and one month after the procedure. Philips iE33 xMATRIX Echocardiography Systems (Eindhoven, The Netherlands) S 5-1 and S 8-3 probes were used for echocardiography. Echocardiography settings were as follows; gain and filter minimal, compress and reject maximum, velocity range -30 and +30 cm/minute, sampling volume width 5 mm. End expirium apnea period was used so that measurements were not affected by respiration.

Both the study and control groups were assessed with echocardiography so as to determine the tricuspid annular plane systolic motion. TAPSE was obtained from apical four chamber view from the intersection of tricuspid annulus free wall by M-mode trace. Pulse wave sampling volume was placed on the corner of the right ventricle which is next to the tricuspid lateral leaflet in apical four chamber view in order to obtain right ventricle tissue Doppler. Doppler trace obtained by this method was used to record ET, IRT and ICT as well as to calculate MPI-Tei index (MPI=ICT+IRT/ET). All of the echocardiographic measurements were performed during the three heart cycles and mean values were recorded. All data of the study group were recorded one day before, and one day and one month after the procedure, and intragroup comparisons were performed. All the data of the study group were also compared with the control group.

Statistical analysis

Descriptive statistical methods (mean ± standard deviation) were used for the assessment of data. Other specific tests were also used including variate analysis for the repetitive measurements of multiple groups, Newman-Keuls multiple comparison test for the comparison of subgroups, Student's t test for the comparison of dual groups, chi-square test for the comparison of qualitative data, and Pearson correlation test for the determination of the relationship between the variables. *P* values less than 0.05 were considered as statistically significant.

RESULTS

Patients' mean pulmonary blood flow/systemic blood low was 1.7±0.4 (range, 1.6 to 2.2), mean apical four chamber 2D view ASD diameter was 14.6±1.7 (range, 12 mm to 18 mm), total septum diameter was 40.2±1.2

Table 2. Tricuspid annular peak systolic excursion and tissue Doppler parameters

	Control group (n=35)	Study group (n=46)	
	Mean±SD	Mean±SD	
Tricuspid annular peak systolic excursion (mm)		17.5±1.9	<0.001
Before procedure			
After procedure 1st day		19.1±2.6	>0.05
After procedure 1st month	20.4±2.3	20.2±2.3	>0.05
Isovolumic contraction time (msc)			
Before procedure		64.1±12.4	<0.001
After procedure 1st day		54.1±11.3	<0.001
After procedure 1st month	37.2±5.2	38.5±7.2	>0.05
Isovolumic relaxation time (msc)			
Before procedure		63.3±12.4	<0.05
After procedure 1st day		53.3±13.6	<0.05
After procedure 1st month	37.2±5.1	38.7±11.3	>0.05
Ejection time (msc)			
Before procedure		226.2±38.5	>0.05
After procedure 1st day		227±30.7	>0.05
After procedure 1st month	229±19.0	228.5±24.8	>0.05
Myocardial performance index			
Before procedure		0.6±0.1	<0.05
After procedure 1st day		0.5±0.1	<0.05
After procedure 1st month	0.3±0.1	0.3±0.1	>0.05

SD: Standard deviation.

(range, 45 mm to 36 mm), and mean device diameter was 16.4±3 (range, 14 mm to 20 mm). Mean procedure time was 25.4±5.6 minutes (range, 20 minutes to 45 minutes) and mean scopy time was 9.3±1.4 minutes (range, 7 minutes to 23 minutes).

Tricuspid valve annular plane systolic excursion and tissue Doppler parameters of study and control groups are shown in Table 2. Mean TAPSE values of the study group before closure, and one day and one month after the closure were 17.5±1.9 mm, 19.1±2.6 mm, and 20.2±2.4 mm, respectively. Mean TAPSE values of control group were 20.4±2.3 mm. Mean TAPSE values before closure were significantly lower compared to control group ($p<0.05$). Immediately one day and one month after closure, TAPSE values increased significantly ($p<0.05$). There was no statistically significant difference in the mean TAPSE values after one day and one month of closure ($p>0.05$).

Mean ICT (msc) and IRT (msc) values of the study group before, and one day and one month after the closure were as follows; 64.1±12.4, 54.1±11.3, 38.5±7.2, and 63.3±12.4, 53.3±13.6, and 38.7±11.3, respectively. ICT (msc) and IRT (msc) values of the study group before and one day after the closure were significantly higher in comparison with the control group ($p<0.05$). Before the procedure, there was no significant difference in the mean ET (msc) values of study and control groups ($p>0.05$). After closure, ICT and IRT were shortened, ET did not change significantly. There was no statistically significant difference in the mean ICT (msc) and IRT (msc) values after one month of closure compared to control group ($p>0.05$) (Table 3).

Mean MPI-Tei index values of the study group obtained before closure and one day after closure were 0.6±0.1 and 0.5±0.1, respectively, and were significantly higher than the values of the control group (MPI=0.3±0.1), ($p<0.05$). One month after the procedure, MPI values decreased markedly (0.3±0.1) and there was no statistically significant difference between two groups in terms of MPI.

DISCUSSION

During the last decade, there has been a remarkable change in the treatment strategy of ASD, shifting the therapeutic gold standard from surgery to transcatheter closure, along with refinements and the evolution of device technology. Transcatheter closure of secundum ASD has the advantages of fewer complications, shorter hospitalizations, reduced need for blood products, less discomfort for patients, and no incisional scar. It has a high success rate, obviates the need for cardioplegia and cardiopulmonary bypass and it is also easy to deploy and reposition, which all render it a method of choice.

It is debatable whether the transcatheter closure of ASDs affects the RV function.[1,2] Studies show that RV function is preserved after transcatheter closure of ASDs.[1-3] Also, RV dysfunction has been encountered after surgical closure of ASDs.[3]

Right ventricular EF is difficult to assess both with accuracy and ease.[4] TAPSE is one of the standard measurements that give quantitative data about RV functions. The most active part of the RV is its basal segment as the longitudinal/axial motion along the RV long axis is the most powerful one contributing the global function. Atrioventricular valve annulus motion becomes important when we accept the fact that during the heart cycle, the apex itself is almost stationary, its circular motion is small in size, and rotation motion is minimal.[10] Although reference values of TAPSE for adults are readily available, values of TAPSE for children are limited. When compared with RVEF, low TAPSE values are closely related with RV dysfunction.[10] Studies demonstrated that TAPSE correlates well with RVEF, which supplies data about RV systolic function based on the idea that it provides information about global functions of the right ventricle.[4-5,11]

Dhillon et al.[12] found that TAPSE values obtained before closure were significantly lower than the control group in their study. They also showed that TAPSE

Table 3. Tricuspid annular peak systolic excursion and tissue Doppler parameters before, and one day and one month after the closure (Newman-Keuls multiple comparison test)

	TAPSE (mm)	ICT (msc)	IRT (msc)	ET (msc)	MPI
	p	*p*	*p*	*p*	*p*
Before procedure/after procedure 1st day	0.009	0.023	0.0001	0.056	0.023
Before procedure/after procedure 1st month	0.014	0.0001	0.0001	0.067	0.024
After procedure 1st day/before procedure 1st month	0.524	0.0001	0.0001	0.578	0.015

TAPSE: Tricuspid annular peak systolic excursion; ICT: Isovolumic contraction time; IRT: Isovolumic relaxation time; ET: Ejection time; MPI: Myocardial performance index.

values obtained one day after the procedure did not differ from the ones obtained before the procedure and there was no significant difference between the values of control and the study groups three months after the procedure. Ağaç et al.[13] did not detect any significant difference between the TAPSE values obtained before and one month after the procedure. Their study showed that TAPSE values of patient group were significantly higher than the values of control group, which was interpreted that RV function was above normal before the irreversible damage took place. They concluded that decreased TAPSE after closure procedure does not really reflect decreased RV function, but it is actually related with the normalization of right ventricle geometry after the cessation of the shunt and its ability to pump effectively despite its reduced function.[13] In our study, mean TAPSE values of study group before the closure was significantly lower than the control group. We think that this outcome may be related with the increased volume load of right ventricle and relative decrease in RV function. Our study differs from the study conducted by Ağaç et al.[13] since our study group's TAPSE values were lower than the control group. However, their study consisted of adult patients, which may explain the difference. There was no significant difference in the mean TAPSE values of our study and control groups one day and one month after the closure. Mean TAPSE values obtained before the closure were significantly lower than the ones obtained after one day and one month of the closure. There was no statistically significant difference in the mean TAPSE values one day and one month after the closure.

Berger et al.[1] compared surgical and transcatheter closure of ASDs and demonstrated that longitudinal muscle fibers are badly affected by cardiopulmonary bypass and RV function improved later in surgically closed defects. We could not compare surgical ASD closure with transcatheter closure, as the number of surgical ASD closures is limited in our unit.

Yılmazer et al.[14] showed that MPI increases more one day after the closure; however, it tends to fall below the values obtained before the procedure in the first and third month controls. The increase in the first day is attributed to decreased RV function due to the drop of volume load on the right ventricle. The study conducted in 2009 by Ding et al.[15] showed that ICT and IRT prolonged, ET shortened and MPI increased in the ASD patients compared with the control group. In this study, ICT and IRT significantly shortened, ET values did not differ, and MPI substantially decreased three days after the closure. This was attributed to the cessation of right ventricle volume load and improvement of ventricular septal motion. Similarly, in our study, the mean ICT (msc) and IRT (msc) values obtained before the closure were significantly higher than the control group and there was no significant decrease one day after the closure. However, there was a considerable decrease one month after the closure, which did not differ from the control group. There was no significant difference in the mean ET (msc) values of study and control groups before, and one day and one month after the closure. Substantial increase in ET (msc) may be explained by the fact that mean ET values before the closure were in normal ranges so that it did not affect the statistical evaluation. Mean MPI-Tei index values were significantly higher in the study group than the control group in our study. Although MPI tended to decrease after the closure, there was no significant difference between the study and the control groups one month after the closure. These findings are similar with the literature. There was no significant difference in the long-term follow-up results of patients whose ASDs were closed by devices and control group in the study of Cheung et al.[16] Furthermore, Pascotto et al.[17] found results similar to our study where MPI decreased in the first day of the closure relative to the values obtained before the procedure and normalized in the follow-up. Pauliks et al.[18] reported in their 39-patient study that RV MPI were in normal ranges before the closure and stated that closure did not effect MPI. They concluded that chronic volume load had minimal effect on ventricle regional motion. Eidem et al.[19] did not detect any difference between the MPI of ASD patients and control group and also could not find any significant change in MPI values of patients whose ASDs were closed by devices. They inferred that this was due to the minimal effect of chronic volume load on right ventricle. However, age distribution was wide in these two studies, which may have affected the results.

Our study has some limitations because surgical closure is limited in our unit.

In conclusion, transcathater closure of atrial septal defects led to increased tricuspid valve annular plane systolic excursion and decreased right ventricular myocardial performance index in early period. Compared with control group, high myocardial performance index and low tricuspid valve annular plane systolic excursion measurements before closure suggest decreased right ventricular function. Markedly decreased myocardial performance index and increased tricuspid valve annular plane systolic excursion after transcathater closure show that right ventricular

function improves after transcathater closure of atrial septal defects in early period.

Declaration of conflicting interests

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