Assessment of right ventricular function by isovolumic contraction acceleration before and after percutaneous closure of atrial septal defects: A preliminary study

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Abstract

Objective: The main purpose of present study was to investigate the impact of percutaneous closure of atrial septal defect (ASD) on right ventricular (RV) systolic function assessed by tricuspid annular isovolumic myocardial acceleration (IVA) that is independent of preload and afterload changes.

Methods: A prospective cohort study was designed involving twenty five patients with secundum type ASD whom were successfully closed percutaneously between 2009 and 2011. Standard transthoracic echocardiography and tissue Doppler imaging were performed in all patients 12 to 24 hours before and one month after closure. Paired t test was performed to determine the statistical significance of variables before and after closure.

Results: Significant decreases were observed in RV end-diastolic diameter, RV/left ventricular (LV) end-diastolic diameter ratio, right ventricular systolic myocardial velocity (Sm), right ventricular early myocardial velocity (Em) and right ventricular late myocardial velocity (Am) in the control echocardiography in the first month when compared with pre-procedure values. While significant increase was observed after procedure in right ventricular IVA (3.4±1.3 m/sec^2 vs. 4.2±1.8 m/sec^2, p=0.001), no significant change was observed in right ventricular global performance index, in right ventricular Em/Am ratio and left ventricular ejection fraction.

Conclusion: Percutaneous closure of ASD resulted in recovery of right ventricular function as early as 1 month after closure.

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Key words: atrial septal defect, right ventricular function, transcatheter closure, tissue Doppler imaging, isovolumic acceleration

Introduction

Atrial septal defect (ASD) is the most commonly encountered congenital heart disease in adults and constitutes 10% of all congenital heart diseases (1). Volume loading via ASD may lead to the several adverse effects including right ventricular (RV) systolic dysfunction (2). Transcatheter closure of ASD has gained popularity and it is being regarded as a first line treatment in most cases of ASD (3). Impact of closure of ASD on RV function was assessed by different techniques in short and long term and most studies have found improved RV function (4). Since most frequently used techniques, especially echocardiographic parameters are load dependent, there is still uncertainty whether these techniques demonstrate improvement of right ventricular function or only reflect RV volume unloading (5).

Recent studies have demonstrated that tricuspid annular isovolumic myocardial acceleration (IVA) determined by tissue Doppler (TD) is a reliable parameter in the evaluation of right ventricular systolic functions independent of preload and afterload changes (6). In present study, we aimed to investigate the impact of ASD closure on right ventricular systolic function assessed by IVA.

Methods

Study design

Patients with secundum type ASD, who were referred to Ahi Evren Cardiovascular and Thoracic Surgery Training and Research Hospital, for percutaneous closure, were prospectively enrolled to the study between 2009 and 2011.

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Study population

The study cohort consisted of 25 patients, predominantly female (84%) with the following inclusion criteria; presence of secundum type ASD and suitability for percutaneous closure. Criteria for exclusion; were determined as inadequate echocardiographic image quality, chronic obstructive pulmonary disease, acute coronary syndrome, diseases such as cardiomyopathy and presence of rhythm irregularities such as atrial fibrillation and AV conduction defects. Also no patients had significant tricuspid valve regurgitation before procedure.

Study protocol

The study protocol was conformed to Declaration of Helsinki. Local Ethics Committee approved the study and written consent was taken from the study participants. Physical examination was done at admission with clinically oriented history taking. A through echocardiographic examination was performed before procedure. Patients were recalled for a control physical and echocardiographic examination a month after closure.

Baseline clinical examinations

Clinical history included data on the type of clinical symptom, symptom severity, and duration of symptom, age, sex, concomitant disease and cardiovascular risk factors.

Transthoracic echocardiography and Doppler imaging

Standard transthoracic echocardiography and tissue Doppler imaging (TDI) were performed in left lateral decubitus position in all patients 12 to 24 hours before the procedure and one month later after closure. Procedure was performed using Vivid-3 echocardiography device (GE Vingmed, Horten, Norway) with a 2.5 MHz "phased array transducer" according to criteria suggested by American Echocardiography Society. Doppler records were carried on with a record speed of 100 mm/sec with simultaneous single derivation ECG record. All the measurements were performed in three consecutive cycles and mean values were recorded.

Tricuspid valve regurgitation was detected at the apical four-chamber view by color Doppler echocardiography. Trans-tricuspid retrograde velocities were obtained using continuous-wave Doppler. Systolic pulmonary artery pressure was estimated from the peak pressure gradient calculated from three consecutive beats using the modified Bernoulli formula ($\Delta P=4V^2$) and the right atrial pressure derived by the diameter of the inferior vena cava and the collapsibility index.

Pulsed TDI was performed to measure systolic and diastolic myocardial velocities at the basal level of the RV free wall. Peak myocardial isovolumetric contraction velocity (IVV), peak myocardial systolic velocity (Sm), peak early and late diastolic velocities (Em and Am), isovolumetric contraction time (IVCT), isovolumetric relaxation time (IVRT) and ejection time (ET) were measured.

All Doppler measurements were performed at the end of the expiration in order not to affect flow parameters with respiration and to be more consistent. Ejection fraction for left ventricular systolic functions was determined with Teicholz formula. Right ventricular M-mode, tissue Doppler records, IVA and MPI measurements were performed for right ventricular systolic and diastolic function indicator. The right ventricular myocardial performance index (MPI) was calculated as the ratio between the sum of the isovolumic contraction time (ICT) and isovolumic relaxation time (IRT) divided by the ejection time (ET): MPI=(ICT+IRT)/ET (Fig. 1). Peak myocardial speed during isovolumic contraction was defined as IVV (m/sec) and time elapsed to reach peak speed was defined as acceleration time (AT). And IVA was calculated with the following formula IVA=IVV/AT (Fig. 2).

ASD closure procedure

Transcatheter closure procedure was performed in the angiography laboratory. Amplatzer septal occluder (AGA Medical Corp., Golden Valley, MN, USA) and Occlutech Fingulla occluder (Occlutech GmbH, Helsingborg, Sweden) devices were used for

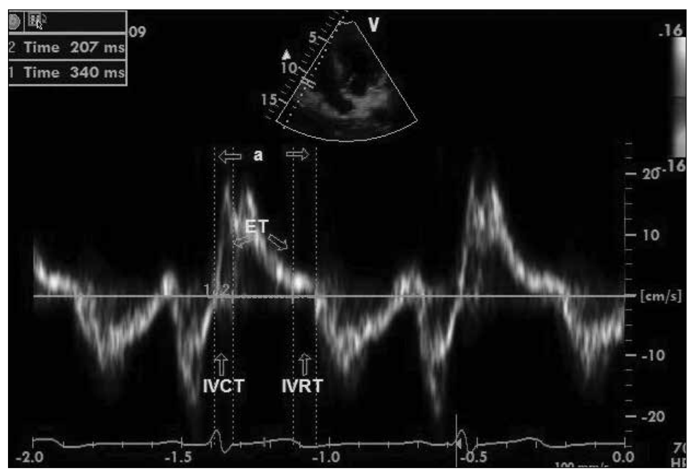

Figure 1. Right ventricular global performance index calculation ET - ejection time; IVCT - isovolumetric contraction time; IVRC - isovolumetric relaxation time, a - time spent between closure and reopening of tricuspid valve

MPI=(IVCT+IVRT)/ET=((a)-(ET))/(ET), MPI - myocardial performance index

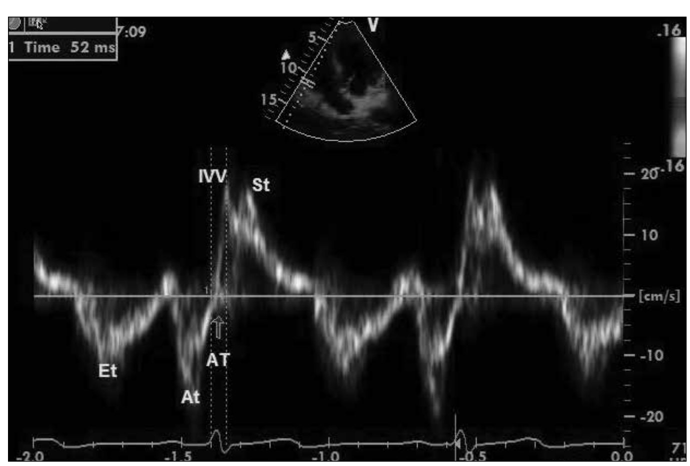

Figure 2. Records of tissue Doppler and calculation of right ventricular IVA. At- late diastolic myocardial velocity, AT - isovolumic acceleration time; Et - early diastolic myocardial velocity; IVCT - isovolumetric contraction time; IVV - peak myocardial speed during isovolumic contraction; ST - systolic myocardial velocity. IVA=IVV/AT

Table 1. Summary of echocardiographic and demographic characteristics (n=25)

	Mean±SD	Range
Females, n (%)*	21 (84%)	
Males, n (%)*	4 (16%)	
Age, years	40±17	13-74
ASD diameter with TTE, mm	17.7±5.9	5-27
ASD diameter with TEE, mm	19.3±6.1	7-31
Stretched diameter with fluoroscopy, mm	22.4±6.0	11-32
Total septum length with TTE, mm	50.0±6.6	36-61
Device size, mm	24±6	12-36
PASP, mm Hg	34.4±7.6	23-48
QP/QS	3.2±1.1	1.3-5.2

PASP - pulmonary artery systolic pressure; TEE - transesophageal echocardiography; TTE - transthoracic echocardiography
Data are expressed as mean±SD
*Data are expressed as n (%) for cathegorical variables

closure. After approval of the patient was received, sheath was placed to femoral vein with needle puncture after local anesthesia was performed to right inguinal area. Right heart was reached through catheter route. An appropriate sizing-balloon catheter was pushed forward to interatrial septum by cutaneous passage over 0.035 inch ultra-stiff exchange guide wire placed in left upper pulmonary vein or left atrium appendix with an open catheter to measure the stretched diameter of the defect. The balloon was blown up with diluted contrast material (1:5) till indentation related to ASD was observed and shunt flow with colored Doppler has disappeared. ASD defect diameter in different positions was measured via TEE or TTE and with fluoroscopy in 40 degrees left anterior oblique (LAO). Then appropriate sized device was pushed forward to shunt region through catheter route. Disks of the device were positioned to stand in both sides of the septal wall. Residual shunt was evaluated following the procedure by TEE or TTE. Later on, implanted device was freed from catheter and the procedure was concluded with removal of catheter. One gram cefazolin for infective endocarditis prophylaxis and 100 IU/kg heparin was administered to all patients during the procedure and after the procedure 300 mg aspirin was suggested to be used at least for 6 months.

Statistical analysis

Evaluations were made with SPSS 13.0 (SPSS Inc., Chicago, IL, USA) program. Continuous variables and categorical changes were respectively defined as mean±standard deviation and percentages. Echocardiography parameters of pre and post procedure were compared using paired-t test. A p values of <0.05 was considered statistically significant.

Results

Baseline characteristics

Baseline echocardiographic and some demographic characteristics of patients were shown in Table 1. There were 21 female and 4 male patients with mean age 40±17 years. Mean ASD diameters with TTE and TEE were 17.7±5.9 and 19.3±6.1 mm, respectively. Mean stretched diameter with fluoroscopy and corresponding device size were 22.4±6.0 and 24±6, respectively.

Table 2. The effects of percutaneous ASD closure procedure on right ventricular functions

	Before closure	After closure 1 month	*P* value*
LV EF (%)	62.2±8.7	63.6±7.3	=0.494
Right atrium diameter, mm	47.7±7.9	40.7±6.4	<0.001
RV end-diastolic diameter, mm	43.2±9.8	35.7±5.7	<0.001
LV end-diastolic diameter, mm	37.4±6.5	39.1±4.5	=0.044
RV/LV end-diastolic diameter ratio	1.2±0.25	0.9±0.15	<0.001
Early diastolic tricuspid annular velocity, cm/sec	14.6±3.5	12.7±2.9	=0.04
Late diastolic tricuspid annular velocity, cm/sec	16.5±3.0	14,0±5.7	=0.009
Tricuspid systolic annular velocity, cm/sec	16.9±3.2	14.0±3.1	=0.003
Em to Am ratio	0.96±0.4	1.03±0.5	=0.571
RV global MPI	0.34±0.14	0.40±0.14	=0.09
RV IVA, m/sec^2	3.4±1.3	4.2±1.8	=0.001

EF - ejection fraction; IVA - isovolumic myocardial acceleration; LV - left ventricle; MPI - myocardial performance index; RV - right ventricle
Data are expressed as mean±SD.
*Treatment effect is analyzed with paired t-test

Echocardiographic measures

Table 2 demonstrates echocardiographic findings before and after the closure of ASD. Significant decreases were observed in RV end-diastolic diameter (43.2±9.8 vs. 35.7±5.7, p<0.001), RV/LV end-diastolic diameter ratio (1.2±0.25 vs. 0.9±0.15, p<0.001), right ventricular systolic myocardial velocity (Sm) (16.9±3.2 vs. 14.0±3.1, p=0.003), right ventricular early myocardial velocity (Em) (14.6±3.5 cm/sn vs. 12.7±2.9 cm/sn, p=0.04) and right ventricular late myocardial velocity (Am) (16.5±3.0 cm/sn vs. 14.0±5.7 cm/sn, p=0.009) in the control echocardiography in the first month when compared with pre-procedure values. While a significant increase was observed in right ventricular IVA post-procedure [(before) 3.4±1.3 vs. (after 1 month) 4.2±1.8, p<0.001], no significant change was observed in right ventricular global performance index, right ventricular Em/Am ratio and left ventricular EF.

Discussion

The main finding of present study is that right ventricular systolic function was recovered as early as one month after percutaneous closure demonstrated by IVA. Recovery of conventional echocardiographic parameters of RV function has consistently been reported following percutaneous closure of ASD. Our data support the use of a novel parameter, which is independent from loading conditions, for assessment of early functional recovery after ASD closure.

Right ventricular systolic function has an independent prognostic indicator of morbidity and mortality in patients with congenital heart disease (7). Echocardiography is usual initial test in evaluating RV functions in different clinical situation. But echocardiographic assessment of the RV has inherent challenges stemming from the chamber's complex shape and its extreme sensitivity to loading conditions (5). Doppler methods of tricuspid inflow and pulmonary artery flow velocities, which are influenced by changes in preload and afterload, may not provide robust prognostic information for clinical decision making. RV systolic function can be assessed by the calculation of RV fractional area change (RVFAC). RV fractional area change represents a ''surrogate'' measurement of RV EF and is expressed as a percentage change in the RV chamber area from end-diastole to end-systole, rather than changes in volume. However, detection of RV border is time consuming and not generally possible. These drawbacks may limit the use of RVFAC in assessing RV function.

RV myocardial performance index (RVMPI), or the ''Tei index,'' has been reported to determine RV global systolic and diastolic function by measuring time intervals using standard pulsed or continuous wave Doppler. Significant correlation of Tei index with RV EF by nuclear ventriculography has been shown and it is reported to be less affected by loading conditions than RVFAC (8, 9). Anavekar et al. (10) investigate the effect of ASD closure on RV function through MPI. They found decreased MPI after ASD closure compared to the before closure as early as 1 month later after closure. In contrast to this study, Ding et al. (11) found worsened MPI after one month closure of ASD. Although MPI is considered as a quantitative measure of RV performance, it is affected on conditions of preload and afterload. Therefore, changes in MPI values in these patients may not mean improved or worsened RV function.

Recent studies have demonstrated that tricuspid annular isovolumic myocardial acceleration (IVA) determined by TD is a reliable parameter independent of preload and afterload changes in the evaluation of right ventricular systolic functions. Several studies have demonstrated that small changes in contractile function can be detected by measuring IVA while changes in pre- and afterload within the physiological range did not affect this parameter. A few investigators demonstrated that IVA was independent of preload and afterload changes in showing right ventricular systolic function; and it was not affected from right ventricular pressure volume load (12, 13). Tayyareci et al. (6) pointed out the importance of IVA in the early diagnosis of right ventricular systolic function defect in cases with mitral stenosis. Moreover, it has been found that IVA showed the deterioration in right ventricular functions much earlier than the other parameters (14, 15). Also, in healthy subjects, IVA is unchanged following significant increases in preload and is regarded as a potential measure of contractility. IVA is a useful tool with the highest predictive power to detect early right ventricular systolic impairment in patients with systemic sclerosis (16).

Our study may differ from the previous studies investigating the impact of percutaneous ASD closure on RV function. First of all, measurement of IVA is easier than the other parameters and does not require sophisticated software or post processing. Also, it is the least load dependent parameter that physician may be able to examine the RV function more accurately that has a prognostic impact.

Study limitations

Small number of patients is the major limitation of our study. Also, evaluation in early period just after the closure and lack of results of long follow-ups is the other limitation of our study. However, we aimed to assess the effect of ASD closure on right ventricular functions in early period with IVA. Studies must be designed with this purpose for long term results. Because of technical and ethical issues, we could not use real-time three-dimensional echocardiography and magnetic resonance imaging that may provide more detailed information on RV functions.

Conclusion

We have demonstrated improvement of right ventricular systolic function by a parameter which is not affected by preload and afterload changes. Since right ventricular systolic function has a prognostic impact in congenital heart diseases, IVA may be clinically useful to provide information on recovery of right ventricular systolic function as early as 1 month after closure of ASD.

Conflict of interest: None declared.

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