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ORIGINAL RESEARCH

Comparison of the Response of the Right Ventricle with Endovascular Occlusion and Surgical Closure in Adults with Atrial Septal Defect One Year After Intervention

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Abstract

Background: Use of the Amplatzer septal occluder (ASO) for the closure of secundum atrial septal defect (ASD) has recently become the procedure of choice, while earlier the only treatment for ASD was surgical closure. This study compares the right ventricular indices of the ASO group with the surgical closure group one year after intervention in adults.

Methods: From January 2008 to February 2010, 38 patients with isolated atrial septal defect of the secundum type one year after surgical (n = 20, age = 27 ± 4 years, 13 females, 7 males) or Amplatzer septal occluder closure (n = 18, age = 25 ± 4 years, 12 females, 6 males) were studied. At the same time, thirty-one age-matched normal subjects (age = 26 ± 6 years, 23 females, 9 males) were included as the control group. Strain and strain rate of the right ventricle were measured.

Results: The mean values of strain of the midportion were –26% ± 11.7%, –8.9% ± 4.2%, and 24.5% ± 7.4% ($P < 0.001$). Strain rates of the midportion were –2.19 ± 0.6 s^{-1}, –1.2 ± 0.4 s^{-1}, –1.9 ± 0.6 s^{-1} ($P < 0.001$) in ASO, surgery, and control groups, respectively.

Conclusion: This study showed that the right ventricle might show better performance in the ASO than the surgery group in adults with ASD in midterm follow-up.

Keywords: atrial septal defect, Amplatzer septal occluder, surgery, adults, right ventricle

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Introduction

Atrial septal defect (ASD) is an anatomic defect between the atrial chambers allowing interatrial shunting, which accounts for 10% of congenital heart diseases at birth and as much as 30% to 40% in adults who present with congenital heart problems and often leads to a shortened life expectancy compared to healthy subjects.[1–5]

ASD that results in the right atrial and right ventricular volume overload should be closed. It has traditionally been considered the standard treatment for this type of malformation for more than 45 years.[6,7] Since the first attempt in 1976 by King and Mills,[8] the placement of an atrial septal occluding device has increasingly become the treatment of choice.[9–12] In the last decade, the Amplatzer septal occluder (ASO, one of the commonly used devices) with its unique design had replaced surgical ASD closure as a suitable treatment for secundum ASDs in most pediatric centers.[13,14] However, few reports studied the practicability, outcome, and efficacy of closing ASDs using this device in adults in comparison with surgery in the long term.[15] So, this study compared function of the right ventricle one year after percutaneous and isolated surgical closure of secundum atrial septal defect in adults.

Methods

Patients

The retrospectively studied patients with isolated secundum ASD who had undergone surgical or device ASD closure 1 year earlier were matched by age and function of the right ventricle before the procedure based on echocardiographic indices between January 2008 and February 2010.

The inclusion criteria for both groups included: 1) the presence of a secundum ASD (diameter of $<$35 mm by echocardiography for both groups); 2) a left-to-right shunt with a Qp:Qs ratio of $<$1.5:1 or the presence of right ventricular volume overload that can be assessed by echocardiography or catheterization; 3) the presence of a distance of $<$5 mm from the margins of the ASD to the coronary sinus, atrioventricular valves, and right upper pulmonary vein as measured by echocardiography; 4) successful percutaneous transcatheter occlusion or surgical occlusion and there was no residual shunt, complications, and clinical cardiac dysfunction after procedure; and 5) patients had sinus rhythm before and after atrial septal defect closure. Patients with other congenital or acquired valvular or myocardial disease were excluded. At the end, 20 patients (27 ± 4 years, 13 females, 7 males) were enrolled in the surgery group and 18 (25 ± 4 years, 12 females, 6 males) in the device group. All patients had a transthoracic echocardiogram (TTE) that identified the defect and subsequently had a transesophageal echocardiogram (TOE) to assess the size of the defect and ensure its suitability for percutaneous closure.

Thirty-one age-matched normal subjects (26 ± 6 years, 23 females, 9 males) were included with the following criteria: i) sinus rhythm on electrocardiography with no conduction disorder; ii) absence of coronary artery disease in left ventricular (LV) segments, which was assessed by a normal hyperdynamic response in all segments of the left ventricle to dobutamine stress echocardiography (particularly in the inferior wall and basal segment of the interventricular septum); iii) absence of cardiovascular or other systemic disease; iv) absence of hypertension or diabetes mellitus; v) persons were not on medication that influenced cardiac function; vi) absence of left ventricular outflow tract (LVOT) cavity gradient by DSE; vii) normal function of the right ventricle and the left ventricle; and viii) Laboratory tests, including tests for triglycerides, total cholesterol, high-density lipoprotein cholesterol, creatinine, and glycosylated hemoglobin (HbA1c), were normal.

All participants gave written informed consent for inclusion in the study. The study protocol was approved by the Ethics Committee of the Iran University of Medical Sciences (Tehran, Islamic Republic of Iran).

Surgical closure of the ASD

Standard ASD repair under general endotracheal anesthesia was performed for patients who underwent surgical closure. The right atrium was opened after a sternotomy using moderate hypothermia at 30 °C, CPB aortic cross-clamping, and cold crystalloid cardioplegic arrest. The ASD was closed either by direct suture or by a pericardial or Goretex patch (W.L. Gore Associates, Flagstaff, Arizona). The patients routinely were extubated in the operating room and transferred to the intensive care unit (ICU) for 36 h. Cefazolin (25 mg/kg) was administered intravenously every 8 hours prophylactically until the chest

tubes were removed. The patients were discharged home after three to five days in the hospital, depending on their clinical condition.

Transcatheter closure of the ASD

The device closure protocol and full description of the device has been reported in detail in an earlier paper.[26] Briefly, all procedures were performed under general anesthesia (Midazolam (0.1 mg/kg dose) and ketamine (1 mg/kg dose) were used at the time of induction, and sevoflurane (0.5%) was administered for anesthesia maintenance) with endotracheal intubation and with continuous transesophageal echocardiographic (TEE) monitoring. The device used was the ASO (AGA Medical Corp., Golden Valley, Minnesota). Balloon-sizing of the defect was performed using the stationary dilation balloon-sizing method. A sizing-balloon was inflated with diluted contrast under fluoroscopic and echocardiographic guidance. The echocardiographic guidance was performed using either TEE or ICE guidance using the AcuNav catheter connected to an Aspen echocardiographic system (Acuson Corporation, Mountain View, California) until the appearance of waisting and disappearance of left-to-right shunt. A dose of an appropriate antibiotic was given during the procedure and two doses at 8-h interval were given later. All patients were instructed about infective endocarditis prophylaxis for a total of 6 months after device placement. Aspirin 3–5 mg/kg was initiated 72 h before closure and continued for 8 months after the procedure.

Echocardiography

Two-dimensional (2D) echocardiography, M-mode and TDI (3-MHz probe; Vivid 7, General Electric, Horten, Norway) were carried out with the patient in the left lateral decubitus position at rest.

After acquisition, images with the best endocardial definition were selected and displayed in a quad-screen format alongside the corresponding baseline images. All images were recorded on videotape and digitized in a continuous loop format for side-by-side analysis.

RVOT fs and S velocity (at right ventricle outflow tract annulus) were measured using the M-Mode of the RVOT in parasternal short-axis view and TDI of the basal and mid of the RV in the apical four-chamber view, respectively.

Regional longitudinal deformation (Strain and strain Rate) was quantified in mid and basal ventricular for free wall by SRI. From the mean strain rate (SR) and strain data, peak systolic strain rate (SR_{sys}) and systolic strain ($strain_{sys}$) were calculated in the four-chamber views. Peak $strain_{sys}$ was defined as the magnitude of deformation from end diastole to end systole. Three cardiac cycles were stored from each view in patients with sinus rhythm. Color Doppler myocardial imaging data were analyzed with dedicated software (TVI, GE Healthcare).

Statistical analysis

The sample *t*-test was used for comparison of parametric variables obtained before and after intervention, Independent Student *t*-test was used for comparison of parametric variables between two groups and one-way ANOVA for comparison of values of echocardiographic indices between three groups. Data are mean ± SD. $P < 0.05$ was considered significant. All tests were done with SPSS 16.0 (Statistical Package for Social Sciences) for Microsoft Windows.

Results

Among 38 patients with ASD for 1 year, 20 patients (53%) were in surgery group and the remaining

Table 1. Baseline characteristic of surgery, ASO and control group before procedure.

	ASO	Surgery	Control	*P* value
Number of patients	18	20	31	
Age (years, mean ± SD)	25 ± 4	27 ± 4	26 ± 6	0.08
Female/male (N)	12/6	13/7	23/9	
ASD size (mm, mean ± SD)	23.4 ± 3.2	24.7 ± 2	–	0.104
Weight (kg, mean ± SD)	68 ± 7	65 ± 7	71 ± 9	
Qp:Qs ratio (mean ± SD)	1.9 ± 0.5	2.1 ± 0.7	–	0.09

Abbreviations: ASD, atrial septal defect; Qp:Qs, ratio of pulmonary to systemic blood flow; ASO, Amplatzer septal occluder.

Table 2. The comparison of right ventricle deformation properties in 3 groups.

	ASO (mean ± SD)	Surgery (mean ± SD)	Control (mean ± SD)	*P* value
Strain of basal segment (%)	–26.7 ± 11.7	–8.9 ± 4.2	–24.5 ± 7.4	<0.001
Strain of mid segment (%)	–26.6 ± 12.2	–7.4 ± 3.1	–29 ± 7.1	<0.001
SR of basal segment (s^{-1})	–2 ± 0.6	–1 ± 0.25	–1.6 ± 0.67	<0.001
SR of mid segment (s^{-1})	–2.1 ± 0.6	–1.2 ± 0.46	–1.9 ± 0.6	<0.001

Abbreviations: Strain, strain of peak systolic; SR, strain rate of peak systolic.

18 patients (47%) were in ASO group; also 31 healthy individuals were selected. Baseline characteristics of these three groups are shown in Table 1. One year after the procedure, all patients of surgery and ASO groups had a successful operation and no residual shunts were seen.

The mean values of RVOT fs was 63.9% ± 10%, 58% ± 11%, and 63% ± 12% in surgery, ASO, and control groups, respectively; however, there was no significant difference between these three groups ($P = 0.184$). When compared with ASO group, the surgery group had smaller S velocity in the base-portion (4 ± 1.5 versus 9.7 ± 1.6, $P < 0.001$) and mid-portion (3.6 ± 2 versus 7.6 ± 1.5, $P < 0.001$) of the right ventricle.

In the ASO and control group, all the regional deformation properties of the right ventricular free wall were significantly increased, compared with the surgery group in the two mid- and basal-segments (Table 2). Also, ASO groups showed normal function when compared with the surgery group.

Discussion

ASD is one of the most common congenital heart defects, and it has long been accepted that surgical or transcatheter repair is the treatment of choice.[12,16] There are increasing reports of the short-term follow-up of ASD closure with the ASO or surgery in pediatrics. However, until now there have been few publications to compare mid-term follow-up results between ASO and surgery in adults.[17] In this study, we observed that adults with ASD using ASO device showed better right ventricle response in mid-term follow-up than patients who underwent surgery.

Significant left-to-right shunt in patients with ASD causes volume overload[18,19] and it may lead to delayed right ventricular contraction, abnormal septal motion, and many other problems of the right ventricle. Previous studies evaluated the RV geometric change response to ASD closure by the measurement of a single RV dimension in a long- or short-axis view, or both.[20,21] RV dimension does not adequately reflect the complex geometry of the RV and abnormal function. Measurement of myocardial deformation (strain and strain rate) overcomes the limitation of the conventional tissue Doppler imaging (combination of functional and nonfunctional segment for calculating TDI indices) and is used progressively by the practitioner.[22] This study is one of the few attempts to compare mid-term performance of the right ventricle after surgery and ASO occlusion in patients with previous ASD by the tissue Doppler derived strain rate. The most important result of using strain rate imaging was as follows: 1) in the surgery group, myocardial deformation properties of the right ventricle were reduced, compared with control and device groups; 2) in the ASO group, myocardial deformation properties were not significantly different from the control group. Salvo and colleagues showed that transcatheter ASD closure is also associated with a less negative impact on right-and-left ventricular function as assessed by tissue Doppler imaging.[23] The study by Durongpisitkul showed that ASO is better than surgery.[24]

This difference between surgery and ASO may be due to the independent effect of cardiopulmonary bypass on right ventricular systolic and diastolic function and because right ventricle is particularly susceptible to the problems of cardiopulmonary bypass and intraoperative ischemia.[25]

Conclusion

This study showed that after mid-term follow–up, the right ventricle showed better performance in ASO than in surgery group in adults with ASD and it may

be better to choose ASO procedure for occlusion of atrial defect in adults.

Limitations

It may be better to measure diastolic echocardiographic indices than the systolic ones. Also, further study with a larger population and long-term follow-up may lead to more accurate results.

Disclosure

This manuscript has been read and approved by all authors. This paper is unique and is not under consideration by any other publication and has not been published elsewhere. The authors and peer reviewers of this paper report no conflicts of interest. The authors confirm that they have permission to reproduce any copyrighted material.

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