International Journal of Arrhythmia

RESEARCH Open Access

Assessment of left atrial remodeling using speckle tracking echocardiography after percutaneous atrial septal defect closure in adult patients

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Abstract

Background: Atrial fibrillation (AF) is a well-known, long-term complication of atrial septal defect (ASD) in adults, even after device closure. Left atrial (LA) strain rate applied to the analysis of chamber function has been demonstrated to be an important predictor of LA reverse remodeling. This study aimed to determine the changes in chamber function after device closure of ASD.

Methods: This prospective study enrolled adults with secundum ASD undergoing transcatheter device closure from December 2016 to August 2017. We analyzed the clinical characteristics and LA strain rate before and six months after ASD closure.

Results: A total of 11 patients were enrolled. The mean age was 42.6 ± 9.9 years, and six (54.5%) were females. There was no significant change of conventional echocardiographic parameters after ASD closure. The mean global LA reservoir strain rate before ASD closure was 1.17 ± 0.34 and 0.85 ± 0.30 after ASD closure ($p = 0.030$). The median global LA conduit strain rate was 0.68 (0.42–1.16) and 0.41 (0.16–0.79) before and after ASD closure ($p = 0.213$), respectively. The mean global LA contractile strain rate at the six-month follow-up showed significant improvement compared with pre-procedural strain rate (0.33 ± 0.65 vs. − 0.43 ± 0.38, $p = 0.006$).

Conclusions: LA functional changes occurred during the six-month follow-up, while LA and right atrial (RA) geometric changes were not significant. LA reverse remodeling was proved by restoration of LA late diastolic contractile function.

Keywords: Atrial septal defect, Percutaneous, Closure, Strain rate, Remodeling, Left atrium

Introduction

Atrial septal defect (ASD) is a common adult congenital heart disease. The inter-atrial shunt is associated with a volume overload of the right heart, resulting in right heart failure or pulmonary hypertension. Also, atrial fibrillation (AF) is a common arrhythmia in the disease course of patients with ASD [1]. AF in patients with ASD is increased after the 4th decade of life, and the incidence is

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about 20% in these patients [2]. Surgical repair of an ASD showed a long-term survival benefit but did not decrease the incidence of AF, which showed no difference between percutaneous transcatheter and surgical closure [3].

The chronic volume overload of left to right inter-atrial shunt results in enlargement of the right atrium (RA). RA dilatation and dysfunction pre-existent to device closure are associated with AF development in ASD patients [4]. However, atrium remodeling is not exclusive to the RA [5]. In the left atria (LA), remodeling is a not common to be accompaniment with LA enlargement in younger patients. Therefore, it is difficult to distinguish predictable factors for development of AF by LA size in ASD patients [6]. The factors associated with LA function and the changes in LA regarding myocardium remodeling after device closure should be defined. Deformation imaging using two-dimensional (2D) speckle tracking echocardiography can be used to assess LA function in patients with heart failure, valvular heart disease, and AF [7].

The aim of this study was to assess LA function and remodeling with atrial myocardial deformation properties after percutaneous ASD device closure, which can increase early detection of AF occurrence.

Methods

Study population

This study was a single-center, prospective study. Patients with secundum ASD who underwent successful percutaneous ASD device closure procedure were consecutively included from December 2016 to August 2017. All patients were evaluated via echocardiographic examination before and after the procedure at the six-month follow-up. All patients were followed up at two weeks, three months, six months, and every six months thereafter. Electrocardiogram monitoring was performed at each visit to the outpatient clinic after the index procedure, and development of AF was detected. Patients who complained of palpitation performed a Holter monitoring. Patients with concomitant congenital heart disease, left ventricular (LV) systolic dysfunction, or age younger than 18 years were excluded from the study. All patients provided informed consent, and this study was approved by the Institutional Review Board of Samsung Medical Center, South Korea (IRB No.) 2015-06-001.

Echocardiographic measurement

All patients underwent a conventional transthoracic echocardiographic examination at baseline and at six months after ASD closure. Each patient underwent a standard examination including 2D, M-mode measurement, and conventional Doppler echocardiography. All parameters were obtained based on recommendations from the American Society of Echocardiography and the European Association of Cardiovascular imaging [8]. The peak early E and late A mitral inflow velocities were obtained from the apical four-chamber view with pulsed-wave Doppler, and early e` and late a` were obtained with tissue Doppler imaging. LA and RA diameter and volume were measured in the parasternal long axis view or apical four-chamber view.

The 2D strain rate of LA was measured with speckle tracking echocardiography in apical four-chamber view, performed with a dedicated software package, EchoPAC (GE Healthcare, Chicago, IL, USA). One experienced investigator analyzed the data. We traced the LA endocardium, and the software automatically tracked the region of interest. The strain rate during LV systole and during early and late LV diastole phases was measured by averaging the values of the six segments of LA for evaluating the LA reservoir, conduit, and contractile function (Fig. 1). All the examinations were performed during sinus rhythm.

Statistical analysis

Statistical analysis was performed using SPSS ver. 27.0 software (SPSS Inc., Chicago, IL, USA). Normality in continuous variables was tested with Shapiro–Wilk test. Normally distributed continuous variables were reported as mean ± SD, whereas skewed continuous variables were presented as median (interquartile range, Q1–Q3). Categorical variables were reported with frequency (percentage). The paired *t* test or Wilcoxon's signed rank test was used to compare continuous variables according to the normality test. Intra- and interobserver variabilities of LA strain were assessed by intra-class correlation coefficients (ICCs). A p value < 0.05 was considered significant.

Results

Baseline characteristics

A total of 11 patients (mean age, 42.6 ± 9.9 years; 6 [54.5%] females) were included. The baseline characteristics are shown in Table 1. All patients successfully experienced device closure, and the mean occlusion size was 20.7 ± 8.2 mm (range of 12–33 mm). The mean QP/QS was 2.6 ± 0.8 and the mean pulmonary artery pressure was 18.4 ± 3.4 mmHg during the procedure. The median follow-up duration was 5.8 months (3.6–6.2). No residual shunt was observed in any of the patients at six-month follow-up. There were two patients who showed paroxysmal AF before ASD closure. There was no AF recurrence or new onset AF after ASD closure.

Echocardiographic parameters

The conventional echocardiographic data of the study population are presented in Table 2. There was no significant

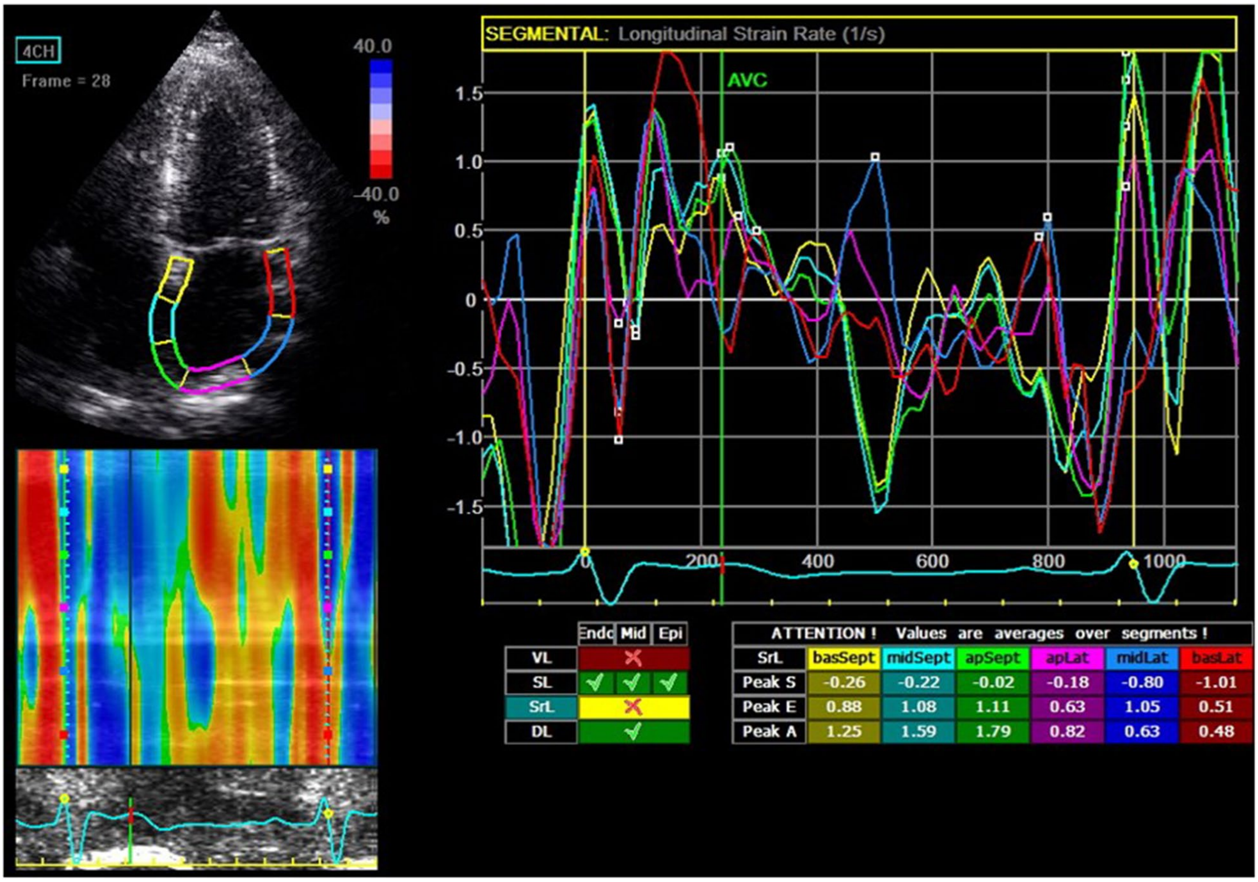

Fig. 1 A representative case of strain rate measurement

Table 1 Baseline patient characteristics

Variables	All patients (*N* = 11)
Age, years	42.6 ± 9.9
Female, *n* (%)	6 (54.5)
Hypertension, *n* (%)	2 (18.2)
Diabetes mellitus, *n* (%)	0
BMI, kg/m^2	24.7 ± 4.8
Paroxysmal AF, *n* (%)	2 (18.2)

BMI Body mass index; *AF* Atrial fibrillation

Table 2 Conventional echocardiographic parameters

	Pre-procedure	Post-procedure at 6 months	*P* value
LV EF, %	62.6 ± 7.0	64.9 ± 5.0	0.277
LA diameter, mm	36.9 ± 7.9	38.5 ± 6.9	0.124
LA volume index, ml/m^2	35.6 ± 10.6	37.7 ± 8.7	0.202
RA diameter, mm	41.6 ± 10.1	38.5 ± 7.4	0.099
Mitral inflow peak E velocity, m/s	0.74 ± 0.13	0.79 ± 0.14	0.240
Mitral inflow peak A velocity, m/s	0.50 ± 0.12	0.56 ± 0.20	0.251
E`, m/s	0.09 ± 0.02	0.09 ± 0.022	0.894
A`, m/s	0.08 (0.07–0.09)	0.08 (0.07–0.10)	0.358
RVSP, mmHg	26.5 (34.5–38.3)	23.6 (21.5–33.1)	0.128

LV Left ventricle; *EF* Ejection fraction; *LA* Left atrium; *RA* Right atrium; *RVSP* Right ventricular systolic pressure

change of conventional echocardiographic parameters after ASD closure. The mean LA diameter and volume index were 36.9 ± 7.9 mm vs. 38.5 ± 6.9 mm ($p = 0.124$) and 35.6 ± 10.6 ml/m^2 vs. 37.7 ± 8.7 ml/m^2 ($p = 0.202$) before and after the procedure, respectively. The mean RA diameters were 41.6 ± 10.1 mm vs. 38.5 ± 7.4 mm ($p = 0.099$) before and after ASD closure. Figure 2 shows the changes in RA diameter after ASD closure (Fig. 3).

The mean global LA reservoir strain rate before ASD closure was 1.17 ± 0.34 and 0.85 ± 0.30 after ASD closure (p = 0.030). The median global LA conduit strain rate was 0.68 (0.42–1.16) and 0.41 (0.16–0.79) before and after ASD closure ($p = 0.213$), respectively. The mean

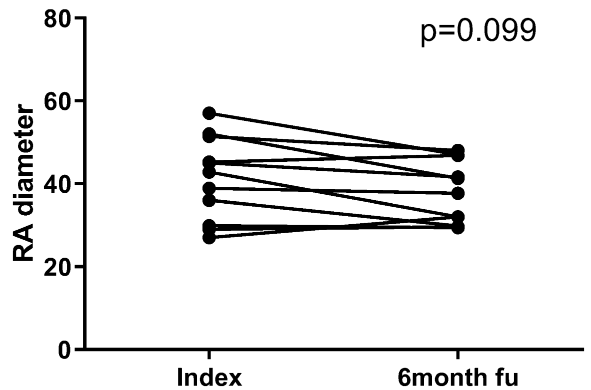

Fig. 2 RA diameter

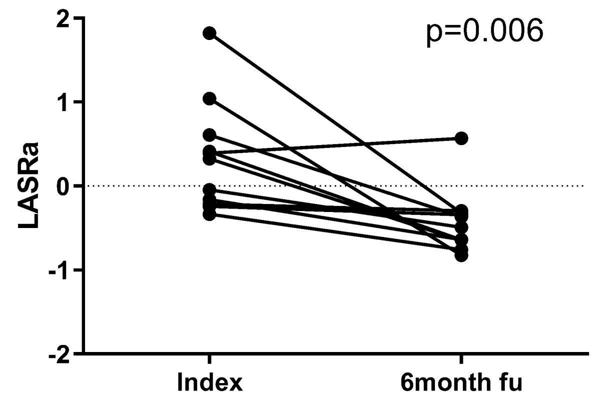

Fig. 4 LA strain rate (late diastole)

global LA contractile strain rate at the six-month follow-up showed significant improvement compared with pre-procedural strain rate (0.33 ± 0.65 vs. − 0.43 ± 0.38, $p = 0.006$). Figure 4 shows the changes in LA contractile strain rate after ASD closure.

There were two patients who showed paroxysmal AF before ASD closure. One patient was a 55-year-old, female who had been diagnosed with AF three months before the procedure. The other patient was a 31-year-old female who had been diagnosed with AF 73 months before the procedure. Neither patient was being treated with anti-arrhythmic agent and was maintaining sinus rhythm during the procedure and during follow-up. The global LA contractile function was improved in both patients after ASD device closure (− 0.34 to − 0.76 in Patient 1, 0.33 to − 0.65 in Patient 2).

The intra-observer correlations for global LA reservoir, conduit, and contractile strain rate were 0.92, 0.88, and 0.94. The interobserver correlations for global LA reservoir, conduit, and contractile strain rate were 0.89, 0.85, and 0.91.

Discussion

We investigated the change of LA function using echocardiographic parameters following ASD device closure. LA functional changes occurred during the six-month follow-up, while LA and RA geometrical changes were not significant. LA reverse remodeling was evidenced by restoration of LA late diastolic contractile function. Also, a paradoxical decrease in LA reservoir function was demonstrated.

LA deformation parameters and reverse remodeling

Strain and strain rate represent global and regional LA function, respectively, based on extent and rate of myocardial deformation [7, 9]. Strain rate can be measured using 2D speckle tracking echocardiography evaluating phasic LA function [9, 10]. LA deformation is divided into three phases of reservoir phase, conduit phase, and contraction phase. The reservoir phase encompasses from the end of ventricular diastole to mitral valve opening, and LA filling is achieved during this phase. The conduit phase occurs at early diastole, from mitral valve opening until onset of LA contraction. The contractile phase occurs at late diastole, from onset of LA contraction until mitral valve closure in sinus rhythm [7, 10]. Reservoir function can be modulated by LA relaxation and preload. Conduit function can be affected by LA afterload and LV relaxation. Contractile function can change with intrinsic LA contraction. There are several reports about LA deformation properties in AF patients.

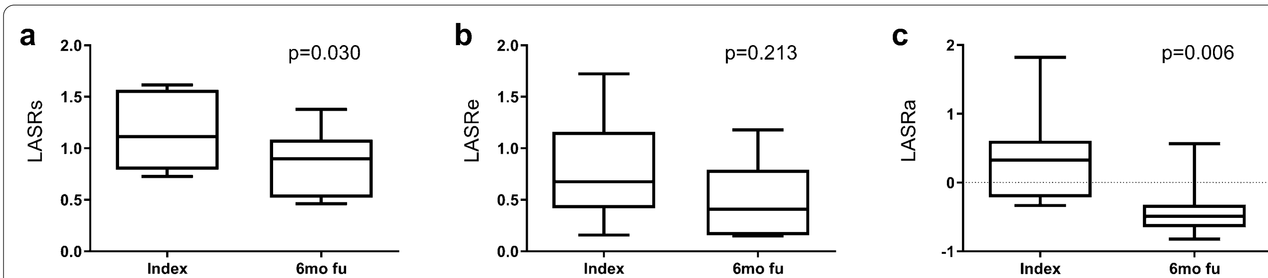

Fig. 3 LA Strain rate before and after ASD closure. **a** The mean global LA reservoir strain rate (paired *t* test), **b** The mean global LA conduit strain rate (Wilcoxon signed rank sum test), **c** The mean global LA contractile strain rate (paired *t* test)

AF is one of the most common causes of LA dysfunction, and remodeling and impaired atrial functions have been associated with increased risk of AF [11]. When reverse remodeling is achieved, strain rate recovers and showed a greater likelihood of maintaining sinus rhythm after rhythm control in AF patients [12–14]. There are several reports about change of LA function after ASD closure, and results were controversial. Sinem et al. reported that strain and strain rate decreased at one month after closure [15]. Another study showed that the LA reservoir and conduit functions were abnormal after a mean follow-up of 44.5 months; however, they did not show baseline parameters before the procedure [16]. In our study, global LA contractile function was improved after six months of follow-up, and global LA reservoir function decreased. Also, there was no change of conventional echocardiographic parameters, including atrial size and Doppler measurements. The improvement of LA contractile function represents LA reverse remodeling before geometric change. Meanwhile, LA reservoir function showed paradoxical decrease after device closure in this study. This decrease might be explained by the differences of chamber preload. In ASD patients, chronic left to right atrial shunt flow causes chronic volume overload to RA, right ventricle (RV), and LA. After closure of ASD, RA, RV, and LA volume overload decrease and result in preload decrease. Strain rate during systole and early diastole were decreased by the decrease in preload. However, late diastole is preload independent [17]. Therefore, the paradoxical decrease in reservoir function was affected by preload decrease, and LA reverse remodeling can be confirmed with improvement of LA contractile function, which is independent of preload change.

Limitations

There were several limitations in this study. First, because this study included a small number of patients, it may have insufficient power to determine the statistical significance of the atrial geometric change. Nevertheless, we demonstrated change in LA function. Second, this study was a prospective cohort study, and we could not demonstrate anatomical change at the six-month follow-up. Additional larger and longer-term follow-up studies should be considered. Third, we did not investigate RA remodeling affecting the occurrence of AF in patients with ASD. Finally, there was no patient who showed recurrence or newly developed AF after device closure. We included a relatively young population, and this could be one of the factors affecting development of AF. More study is needed about LA and RA reverse remodeling in AF recurrence patients.

Conclusion

LA reverse remodeling was demonstrated by restoration of LA late diastolic contractile function. LA functional changes occurred during the six-month follow-up, while LA and RA geometrical changes were not significant. This can assist in early detection of subclinical change and could refine risk stratification and guide therapy for management of AF.

Abbreviations

2D: Two-dimensional; AF: Atrial fibrillation; ASD: Atrial septal detect; BMI: Body mass index; EF: Ejection fraction; LA: Left atrium; LV: Left ventricle; RA: Right atrium; RV: Right ventricle; RVSP: Right ventricular systolic pressure.

Acknowledgements

Not applicable.

Author contributions

JHC, JKH, HRK, TWC, JWK and JYK collected data. JHC, JYK and JH analyzed data and wrote a manuscript. SWP, ISK, JYS, SJP, KMP, YKO, JSK and JH reviewed and revised manuscript. All authors read and approved the final manuscript.

Funding

This study was supported by a grant from the Korean Heart Rhythm Society.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate

All patients provided informed consent, and this study was approved by the Institutional Review Board of Samsung Medical Center, South Korea (IRB No.) 2015-06-001.

Consent for publication

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient/parent/guardian/relative of the patient.

Competing interests

The authors declare that they have no competing interests.

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Received: 7 November 2021 Accepted: 7 July 2022
Published online: 01 September 2022

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