Left and right ventricular speckle tracking study before and after percutaneous atrial septal defect closure in children

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Abstract

Objectives: To analyze the acute and short-term deformation changes of both right (RV) and left (LV) ventricular wall before and after transcatheter closure of atrial septal defect (ASD) secundum in children.

Outcome measures: To determine the feasibility of tissue Doppler and myocardial deformation imaging for evaluating RV and LV functions in children undergoing transcatheter ASD closure.

Patients and methods: A prospective study was performed for 32 children with hemodynamic significant ASD secundum before and 6 months after percutaneous ASD closure in the Pediatric Cardiology Division of Specialized Pediatric Hospital, Cairo University. Speckle tracking echocardiography (STE) of LV and RV global analysis (longitudinal and circumferential strain) before and after ASD transcatheter closure was performed.

Results: The mean age of the patients was 6.01 ± 3.19 (range: $3-9$) years with a female to male ratio of 1.3:1. There was an improvement in the RV and LV myocardial performance index (MPI) 6 months post-ASD closure (RVMPI = 0.46 ± 0.069 vs. 0.38 ± 0.05, $p < 0.0001$; LVMPI = 0.49 ± 0.12 vs. 0.38 ± 0.08, $p < 0.0001$, respectively). By 2D STE, there was a significant improvement in the RV global longitudinal strain (GLS) 6 months post-ASD closure ($-20.17 \pm 3.14\%$ vs. $-25.86 \pm 5.02\%$, $p < 0.0001$). There was a significant increase in the LV end-diastolic volume (EDV) and LV end-systolic volume (ESV) using 4D STE after device closure (LVEDV = 32.96 ± 10.99 mL vs. 44.024 ± 14.9017 mL, $p < 0.0001$; LVESV = 15.16 ± 6.08 mL vs. 21.76 ± 8.34 mL, $p < 0.0001$, respectively). Additionally, there was a significant improvement in the LV GLS after device occlusion ($-19.17 \pm 3.67\%$ vs. $-22.36 \pm 4.72\%$, $p = 0.009$) using 4D TomTec software. There was a significant decrease in the RVEDV (54.65 ± 10.05 mL vs. 15.73 ± 8.67 mL) and RV stroke volume (25.15 ± 6.36 vs. 20.06 ± 7.2) after device occlusion using 4D TomTec software.

Conclusion: By using 4D STE, the LV GLS was significantly improved; in contrast, by 2D STE, the RV volume overload decreased and the RV GLS was improved on short term after transcatheter ASD secundum closure in children.

Keywords: 4D speckle tracking, ASD secundum, Myocardial performance index, Transcatheter closure

1. Introduction

Atrial septal defects (ASDs) constitute $8-10\%$ of congenital heart defects in children. The incidence of ASDs is estimated to be 56 per 100,000 live births [1]. Transcatheter occlusion of ASD secundum is performed worldwide and has become one of the most practiced interventional procedures for structural heart disease, and closure of the defect causes a sudden change in loading conditions of both ventricles [2]. Quantitative evaluation of right ventricular (RV) function remains challenging due to RV complex anatomy and structure [3]. The 4D echocardiography can

overcome 2D limitations by neglecting geometric assumptions and using multiple images to reconstruct the RV chamber [4]. Myocardial strain and strain rate are more accurate than velocities as indices of ventricular contractility, perhaps by eliminating translational artifact, strain rate values appeared to be dependent on pressure overload but less dependent on volume overload than on strain [5].

The aim of this study was to analyze the acute and short-term changes after percutaneous ASD secundum closure by evaluating the RV and LV wall deformations in children using 2D and 4D speckle tracking echocardiography (STE).

2. Patients and methods

A prospective analytical study was performed for 32 children in the Pediatric Cardiology Division of Specialized Pediatric Hospital, Cairo University, with a hemodynamic significant ASD secundum before and 6 months after transcatheter closure of ASD. Children aged from 2 years to ≤18 years, weighing >12 kg, and with a dilated RV were included in the study. An informed consent was obtained from the patients or their legal guardians after the approval of the Ethical Committee of Medical Science of Cairo University. The work complies with the principles of the Declaration of Helsinki in 1964. All patients were submitted to a complete transthoracic echocardiography (TTE) using different echocardiographic modalities such as 2D TTE, tissue Doppler imaging (TDI), and 2D and 4D STE using Philips EPIC 7 (Philips Ultrasound, WA, USA) ultrasound system with X5-1, S8-3, or X7-2 broadband phased-array transducers, depending on the age of the patient. The 2D STE is limited by a number of intrinsic limitations, including loss of speckles due to motion outside the imaging plane and suboptimal reproducibility. More recently, 3D STE has been developed to overcome the limitations of 2D STE [6]. The 4D STE has the potential to overcome some of the intrinsic limitations of 2D STE in the assessment of complex LV myocardial mechanics, offering additional deformation parameters and a comprehensive quantitation of LV geometry and function from a single 3D acquisition. The data were analyzed by Q-Lab (Philips Medical Systems (Philips Ultrasound , WA, USA)) and TomTec softwares (TomTec Imaging Systems, Unterschleissheim, Germany). The 4D RV function by TomTec software allows complete evaluation of the RV and combines 3D and 2D values including end-diastolic volume (EDV), EDV

Abbreviations	
ASD	atrial septal defect
RV	right ventricle
LV	left ventricle
MPI	myocardial performance index
LVEDV	left ventricular end diastolic volume
LVESV	left ventricular end systolic volume
GLS	global longitudinal strain
2D	two dimensional
4D	four dimensional
TTE	transthoracic echocardiography
STE	speckle tracking echocardiography
LAX	long axial view
TAPSE	tricuspid annular peak systolic excursion
E	early diastolic filling velocity
A	late atrial diastolic filling velocity
S	Systolic filling velocity
SLS	systolic longitudinal strain
3D-RVEF	3 dimensional right ventricular ejection fraction

index, end-systolic volume (ESV), ESV index, ejection fraction (EF) and stroke volume (SV), RV longitudinal strain (RVLS), tricuspid annular peak systolic excursion (TAPSE), and fractional area change. The 4D RV function helps to overcome the RV complexity by calculating standard values based on a 3D surface model. Before and 6 months post-ASD closure, the following were performed: (1) assessment of biventricular function, pulmonary hypertension, and TAPSE; (2) TDI for RV free wall, LV lateral wall, and calculation of RV and LV myocardial performance index (MPI), and general data were obtained mostly from four-chamber view within one cardiac cycle; (3) 2D speckle RVLS by Q-Lab analysis (Philips Medical Systems) and TomTec (4D analysis 3.0; TomTec Imaging Systems) for diastolic volume, SV, and TAPSE; (4) 4D LV TomTec (strain) global analysis (longitudinal and circumferential strain); and (5) 4D LV TomTec apical and basal rotation and twist, 4D STE. The 3D data sets were displayed as multiplanar reconstruction images corresponding to four tiles containing three standard long axis (LAX) views (apical four chamber, three chamber, and two chamber) and a short axis view, which is orthogonal to the LAX views. LV boundaries were first manually selected for the three anatomic landmarks (mitral annulus, LV apex, and aortic valve). Adjustments were made in the multiplanar reconstruction images until the landmarks were well positioned in each standard view. The 3D endocardial surface was automatically reconstructed and tracked in 3D space throughout the cardiac cycle. Subsequently, the Beutel revision state displayed a static 3D surface model of the LV (Beutel) automatically calculated by the application.

Finally, the LV was automatically divided into 16 3D segments using the standard segmentation of the American Society of Echocardiography. The curves and maps of the 3D LV global rotation, twist, and torsion analyses were calculated [7].

2.1. Statistical analysis

Data were analyzed using IBM SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA). Continuous numerical variables were presented as mean and standard deviation, and intergroup differences were compared using the independent samples t test. The paired samples t test was used to compare paired numerical data. Categorical data were presented as n (%) or ratio, and differences were compared using Fisher's exact test. Two-sided p values <0.05 were considered statistically significant.

3. Results

The clinical characteristics of the patients with ASD secundum are presented in Table 1. The mean age of the studied patients was 6.013 ± 3.19 years and their mean weight was 20.16 ± 9.65 kg. The majority of them were asymptomatic (16/32; 50%), 10 (31.3%) had an exertional dyspnea, and four (12.5%) had repeated chest infections. The mean size of ASD secundum was 17.95 ± 5.45 mm, whereas the mean size of ASD device was 21.25 ± 5.50 mm (Table 2). The device size ranged from 7.5 mm to 38 mm, eight of them were Amplatzer device [ASO; St. Jude Medical (now Abbott), St. Paul, MN, USA], 18 of them were Hyperion (ASO, Comed BV, The Netherlands), and six of them were Occlutech device (ASO, Helsingborg, Sweden). By TDI, there was a significant change in the RV load with a reduction of early and late atrial velocities as well as a significant improvement in the RVMPI by comparing the data before and 6 months after ASD closure (Table 3). By contrast, the only change observed in the LV by TDI after the procedure was the increase of peak systolic velocity and the improvement of global myocardial function (Table 4). By 2D speckle tracking study of RV, there was a significant increase in the global longitudinal strain (GLS) as well as in the basal–anterior, basal–inferior, and apical before and after the device closure (Table 5). There was a significant improvement in the LV GLS 6 months post-device closure by 2D STE (Table 6). By 4D STE of RV before and after device closure, there was a significant decrease in the RVEDV and SV without any significant change in TAPSE or EF (Table 7). By contrast, 4D speckle tracking study of LV before and 6 months post-ASD closure showed significant changes in the form of increased SV, EDV, ESV, GLS, and the degree of torsion and twist (Table 8).

4. Discussion

This study demonstrated reverse of remodeling both RV and LV using STE after transcatheter ASD closure in children. The assessment of ventricular function following percutaneous ASD closure is complicated by the alteration to loading conditions caused by the elimination of intracardiac shunting [8]. Adverse ventricular interdependence associated with RV volume overload was previously described as "Bernheim effect", in which the interventricular septum bulges into the LV cavity and leads to impairment of LV filling [9]. Deformation imaging is a promising technique to assess regional and global myocardial function in children with heart disease. STE- and TDI-derived deformation measurements were both feasible in children, but the speckle tracking techniques are more user friendly and less time intensive [10]. Furthermore, STE is a technique that provides a quantitative assessment of the motion of myocardial tissue, independently of angle and ventricular geometry, which could detect subclinical myocardial dysfunction [11]. Myocardial deformation is dependent on not only myocardial contractility but also ventricular dimension and pre-/afterload [12,13].

Table 1. Demographic and baseline clinical and electrocardiogram data of the studied population.

Variable		
Age (y)		6.013 ± 3.19
Weight (kg)		20.16 ± 9.65
Body surface area (m^2)		0.73 ± 0.22
Gender	Female	19 (59.4)
	Male	13 (40.6)
Presentation	Asymptomatic	16 (50.0)
	Exertional dyspnea	10 (31.3)
	Repeated chest infection	4 (12.5)
	Feeding difficulty	1 (3.1)
	Trisomy 18	1 (3.1)
ECG	Normal	16 (50.0)
	RAD, RVH	16 (50.0)

Data are presented as mean $\pm$ SD or n (%).
ECG = electrocardiogram; RAD = right axis deviation; RVH = right ventricular hypertrophy.

Table 2. Characteristics of atrial septal defect secundum size and its device.

	Range	Mean $\pm$ SD	Median
ASD size (mm)	7.0–35.0	17.95 ± 5.45	17.0
ASD device size (mm)	7.50–38.0	21.25 ± 5.50	20.0
Types			

ASD = atrial septal defect.

Table 3. Comparison of tissue Doppler imaging measurements of right ventricle before and after device closure (mean ± SD).

TDI data	Before device closure Mean ± SD	6 months post-device closure Mean ± SD	Paired differences Mean ± SD	95% CI	p
RVE' (cm/s)	16.18 ± 3.88	12.73 ± 2.40	3.45 ± 4.58-	−5.10 to −1.7999	0.0002
RVA' (cm/s)	10.65 ± 2.56	8.87 ± 1.41	−1.78 ± 2.97	−2.85 to −0.71	0.0019
RVS' (cm/s)	12.08 ± 1.53	12.45 ± 2.72	0.368 ± 2.51	−0.5391 to 1.2766	0.2248
MPI	0.46 ± 0.068	0.38 ± 0.053	0.07 ± 0.05	−0.09 to −0.05652	<0.0001

A' = late diastolic tissue annular velocity; CI = confidence interval; E' = early diastolic tissue annular velocity; MPI = myocardial performance index; S' = systolic annular velocity; TDI = tissue Doppler imaging.

Table 4. Comparison of tissue Doppler imaging of left ventricle before and after device closure (mean ± SD).

TDI measure	Before device occlusion Mean ± SD	6 months post-device closure Mean ± SD	Paired differences Mean ± SD	95% CI	p
LVE' (cm/s)	15.60 ± 2.99	14.85 ± 2.86	0.75 ± 4.2575	−2.28 to 0.78	0.3267
LVA' (cm/s)	7.28 ± 1.543	8.11 ± 1.84	0.83 ± 2.109	0.06 to 1.52	0.0344
S' (cm/s)	8.97 ± 2.019	10.18 ± 1.61	1.22 ± 2.35	0.36 to 2.05	0.0065
MPI	0.46 ± 0.122	0.38 ± 0.08	0.12 ± 0.07	0.13 to −0.08	<0.0001

A' = late diastolic tissue annular velocity; CI = confidence interval; E' = early diastolic tissue annular velocity; MPI = myocardial performance index; S' = systolic annular velocity; TDI = tissue Doppler imaging.

4.1. Right ventricular echocardiography

In our series, by using TDI, there was a significant decrease in early and late atrial velocities as well as improvement in the RV global myocardial performance 6 months post-transcatheter ASD closure. By contrast, by 4D STE, there was a significant decrease in the RVEDV and SV without a significant change in TAPSE by comparing the data before and after device closure. The increased preload before ASD closure as shown by EDV in RV had high basal RV systolic function following starling law of the heart [14]. It was previously reported that RV volumes decreased significantly in the first month after ASD device closure and continued up to 6 months. There was no change in the global RV systolic function but a high basal RV systolic function decreased after closure. Some patients had impaired diastolic function before closure of defect, which reversed to normal within 6 months after closure [15]. TAPSE is a standard RV parameter that gives quantitative

information about RV function. In previously published studies, a good correlation has been reported between RV functions and TAPSE [16,17]. A significant decrease has been reported in TAPSE after closure of ASD in the first month and at 6 months after closure. The RV will accommodate lower volume after closure of ASD, which leads to pump sufficient SV at decreased functional state [14]. Deformation analyses can differentiate between active and passive myocardial tissue movement [18]. The 4D echocardiography is a reliable quantitation of RV volumes, function, and mass. Also, STE measures actual tissue deformation within the myocardium and global and regional myocardial function [19]. It was previously published that before ASD closure, the RV systolic longitudinal strain (SLS) and GLS were significantly higher than those of the controls. At 1 day after closure, the diameters of right atrium (RA) and RV decreased. All the RV SLS and GLS decreased accordingly and were lower than the

Table 5. Comparison of right ventricular longitudinal strain by 2D speckle tracking echocardiography before and after device closure (mean ± SD).

2D STE measure	Before device occlusion Mean ± SD	6 months post-device closure Mean ± SD	Paired differences Mean ± SD	95% CI	p
Basal anterior (%)	−23.21 ± 6.06	−27.48 ± 6.63	−4.26 ± 7.75	−7.0606 to −1.4707	0.0040
Mid-anterior (%)	−24.75 ± 6.54	−27.2 ± 6.39	−2.44 ± 7.00	−4.9667 to 0.08547	0.0578
Apical lateral (%)	−19.25 ± 5.50	−20.97 ± 5.82	−1.71 ± 5.85	−3.8224 to 0.3974	0.1079
Apical (%)	−21.13 ± 5.10	−24.60 ± 5.92	−3.47 ± 6.31	−5.7509 to −1.1991	0.0040
Septal apical (%)	−22.71 ± 4.98	−25.57 ± 5.14	−2.85 ± 5.04	−4.6783 to −1.0404	0.0031
Mid-inferior (%)	−22.24 ± 4.86	−24.36 ± 6.17	−2.11 ± 5.86	−4.2327 to −0.004843	0.0495
Basal inferior (%)	−20.65 ± 4.98	−24.84 ± 6.97	−4.18 ± 7.95	−7.0549 to −1.3201	0.0056
GLS (%)	−20.17 ± 3.14	−25.86 ± 5.02	−5.68 ± 3.86	−7.1004 to −4.2674	<0.0001

CI = confidence interval; GLS = global longitudinal strain; STE = speckle tracking echocardiography.

Table 6. *Comparison of 2D speckle tracking echocardiography of left ventricular global analysis before and after device occlusion: LV global analysis.*

2D STE measure	Before device closure Mean ± SD	6 months post-device closure Mean ± SD	Paired differences Mean ± SD	95% CI	p
Anterior basal (%)	−21.62 ± 6.07	−26.58 ± 4.97	−4.96 ± 6.46	−7.42 to −2.50	0.0003
Anterior mid (%)	−23.12 ± 5.66	−23.44 ± 10.25	−0.31 ± 9.84	−3.86 to 3.23	0.8572
Anterior apical (%)	−21.34 ± 5.00	−24.59 ± 5.82	−3.25 ± 5.65	−5.28 to −1.21	0.0028
Anteroseptal basal (%)	−20.31 ± 4.16	−21.81 ± 6.93	−1.5 ± 6.67	−3.90 to 0.90	0.2132
Anteroseptal mid (%)	−20.65 ± 3.91	−22.59 ± 7.51	−1.93 ± 7.573	−4.66 to 0.79	0.1579
Anterolateral basal (%)	−22.56 ± 5.32	−26.75 ± 6.55	−4.18 ± 9.032	−7.44 to −0.93	0.0134
Anterolateral mid (%)	−23.37 ± 6.27	−25.093 ± 7.21	−1.71 ± 9.85	−5.271 to 1.83	0.3315
Inferior basal (%)	−20.68 ± 6.36	−24.90 ± 5.78	−4.21 ± 7.51	−6.92 to −1.51	0.0034
Inferior mid (%)	−23.96 ± 6.92	−24.42 ± 7.40	−0.45 ± 8.24	−3.42 to 2.51	0.758
Inferior apical (%)	−23.21 ± 5.71	−28.53 ± 5.21	−5.31 ± 7.73	−8.09 to −2.52	0.0005
Inferolateral basal (%)	−19.56 ± 5.42	−23.38 ± 8.28	−3.82 ± 9.73	−7.33 to −0.31	0.0336
Inferolateral mid (%)	−20.93 ± 4.79	−24.34 ± 7.15	−3.40 ± 6.36	−5.75 to −1.14	0.0049
Inferoseptal basal (%)	−21.81 ± 4.63	−24.09 ± 6.64	−2.28 ± 6.67	−4.68 to 0.12	0.0625
Inferoseptal mid (%)	−19.80 ± 7.34	−23.38 ± 6.93	−3.58 ± 9.53	−7.07 to −0.08	0.045
Lateral apical (%)	−22.53 ± 5.30	−25.93 ± 6.32	−3.40 ± 7.22	−6.01 to −0.80	0.0121
Septal apical (%)	−24.43 ± 6.29	−29.56 ± 4.98	−5.12 ± 6.93	−7.62 to −2.62	0.0002
GLS (%)	−19.60 ± 2.60	−26.22 ± 4.64	−6.61 ± 3.80	−7.99 to −5.24	<0.0001

CI = confidence interval; GLS = global longitudinal strain; STE = speckle tracking echocardiography.

control values. At 3 months after closure, the apical free wall strain, all segments of septal strains, and GLS increased significantly compared with the values obtained at 1 day after closure. In contrast, the diameters of the RA and RV decreased further as well. There were no significant differences in the strains compared with the control values, except for the free wall basal strain [20]. Bussadori et al [21] mentioned that the RVLS works as an indicator of RV function dependent on loading conditions, while strain rate seems to be less dependent on it. Circumferential strain could be used as an indicator of LV response to normalized loading conditions. Ki Ko et al [22] concluded that the longitudinal deformation of the RV basal segment and its remodeling is dependent on volume loading in children with ASD. Also, the decreased RV basal segment deformation in post-closure patients and reverse remodeling of the basal segment might not be achieved until 6 months post-closure [23]. Real-time 3D echocardiography (RT3DE) may play a potential role in the noninvasive evaluation of RV systolic function in patients with ASD. The impairment of RV global and regional systolic function in patients with open and closed ASD could be detected by RT3DE. RT3DE-derived systolic function parameters are less preload dependent than 2D echocardiographic parameters. RV global EF and regional EF in the inflow compartment are negatively correlated with RV after load in patients with ASD [14]. Also, Jategaonkar et al [24] found that volume overload in patients with ASD is associated with increased strain values and strain values return to normal after abolishment of the volume overload with percutaneous ASD closure. In contrast, Teo et al [25] reported that a significant reduction in RV volumes at 6 months after ASD closure and RVEF was significantly increased in cardiovascular magnetic resonance (CMR). CMR is an accurate and reproducible imaging modality for the assessment of cardiac function and volumes [25]. In contrary, there was reportedly no change in the global RV systolic function, but a high basal RV systolic function decreased after closure. Some patients had impaired diastolic function before closure of defect, which reversed to normal within 6 months after closure [26].

Table 7. *Comparison of 4D speckle tracking echocardiography of right ventricular global analysis using TomTec before and after device closure.*

4D STE	Before device closure Mean ± SD	6 months post-device closure Mean ± SD	Paired differences Mean ± SD	95% CI	p
RVEDV (mL)	54.65 ± 10.04	45.32 ± 15.73	8.66 ± 17.70	1.3601 to 15.9759	0.0221
RVSV (mL)	25.14 ± 6.35	20.06 ± 7.20	4.91 ± 7.13	1.9718 to 7.8602	0.0021
TAPSE (mm)	11.46 ± 2.50	13.21 ± 2.82	1.75 ± 3.08	0.4475 to 3.0525	0.0107
RVEF (%)	45.08 ± 8.57	46.32 ± 6.48	1.25 ± 10.34	3.0213 to 5.5213	0.5515

CI = confidence interval; RVEDV = right ventricular end-diastolic volume; RVEF = right ventricular ejection fraction; RVSV = right ventricular stroke volume; STE = speckle tracking echocardiography; TAPSE = tricuspid annular plane systolic excursion.

Table 8. Comparison of 4D speckle tracking echocardiography of left ventricular global analysis using TomTec before and after device occlusion: LV global analysis.

4D TomTec measures	Before device closure Mean ± SD	6 months post-device closure Mean ± SD	Mean ± SD	Paired differences 95% CI	p
LVEDV (mL)	32.96 ± 10.98	44.02 ± 14.90	11.06 ± 10.40	6.7681 to 15.3599	<0.0001
LVESV (mL)	15.16 ± 6.07	21.76 ± 8.34	6.6 ± 5.86	4.1776 to 9.0224	<0.0001
LVSV (mL)	19.96 ± 7.36	27.62 ± 9.83	7.652 ± 6.41	5.0022 to 10.3018	<0.0001
LVEF (%)	57.44 ± 8.07	58.68 ± 7.48	1.24 ± 8.36	−2.2126 to 4.6926	0.4657
LV mass (g)	48.48 ± 19.25	62.05 ± 25.48	13.57 ± 16.34	6.8310 to 20.3210	0.0004
LVGLS (%)	−19.17 ± 3.68	−22.36 ± 4.72	−3.19 ± 5.64	−5.5203 to −0.8637	0.0093
LVGCS (%)	−20.75 ± 11.17	−26.35 ± 6.59	−5.59 ± 11.67	−10.4137 to −0.7791	0.0246
LVSDI	5.05 ± 1.64	5.178 ± 2.08	0.12 ± 2.59	−0.9943 to 1.2476	0.8169
LV twist (°)	10.95 ± 4.33	15.90 ± 5.39	4.95 ± 5.18	2.8171 to 7.0949	0.0001
LV torsion (°)	2.136 ± 0.56	2.89 ± 0.87	0.76 ± 0.89	0.3902 to 1.1298	0.0003

CI = confidence interval; LVEDV = left ventricular end-diastolic volume; LVEF = left ventricular ejection fraction; LVESV = left ventricular end-systolic volume; LVGCS = left ventricular global circumferential strain; LVGLS = left ventricular global longitudinal strain; LVSDI = left ventricular systolic diameter index; LVSV = left ventricular stroke volume.

4.2. Left ventricular echocardiography study: conventional and nonconventional modalities

In our cohort, by TDI, LVMPI significantly improved as well as the peak systolic velocity of LV lateral wall increased after device closure. This finding might be explained by the restoration of LV compression and the increase in LV filling [8]. Furthermore, Raymond et al [27] concluded that the LV geometry is altered with mild impairment of LV filling and decrease in LV dimensions. After closure of the defect, RV and RA dimensions tend to decrease, but EDV and dimensions of the LV increase in the following period, and return to normal sooner.

In our cohort, there was a significant increase in the LVEDV and GLS 6 months post-ASD closure. In contrast, it was previously published that circumferential strain was increased significantly 24 hours after ASD closure and might be used as an indicator of LV response to normalized loading conditions [14,15]. LVLS was not affected early after ASD closure may be due to later improvement after 6 months after closure [13]. It has been postulated that in patients with ASD due to volume overload of the RV, adverse ventricular interdependence occurs and the septum bulges into the LV cavity, which leads to impairment of LV filling, and consequently, LV systolic and diastolic functions worsen. This situation has been reported to be resolved following percutaneous ASD closure [28–30]. Gao et al [31] reported that LV systolic function can be improved through normalization of interventricular septum abnormal motion after transcatheter ASD occlusion, although transcatheter occlusion did not have a significant impact on intrinsic LV systolic synchronicity in patients with ASD. The long standing volume overload by percutaneous closure causes an early increase in left atrial (LA) and LV longitudinal deformation that correlates with the magnitude of ASD and decreased in 1 month after closure [32]. Our present study demonstrated LV torsional deformation in ASD patients post-transcatheter device closure. The transcatheter device closure increased twisting degree and rotational motion of the LV at basal by using the 4D speckle tracking method. The LV torsion which is the difference between the rotation of the base and apex relative to its LAX has improved immediately after device closure LV. Our results are in harmony with the study by Razak et al [33] who concluded that LV twisting and torsion at a younger age was improved after the ASD closure.

This is in contrary to the findings by Dong et al [34] who reported that LV basal rotation improved significantly, while apical rotation remained unchanged after transcatheter ASD closure.

4.3. Limitations of the study

The results were obtained from a single medical center (Pediatric Cardiology Division of Specialized Pediatric Hospital, Cairo University), and the sample size was rather small. The results were not compared with normal controls and cardiac magnetic resonance imaging evaluation of RV and LV volumes and functions were not included in this study.

5. Conclusion

Percutaneous closure of ASD in pediatric age leads to reverse remodeling of both LV and RV, which were assessed by STE.

Acknowledgments

Conflict of interest

The authors declare that there is no conflict of interest.

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