Evaluation of Left Ventricular Rotational Deformation by Non-Conventional Echocardiography Before and After Transcatheter Closure of Large Secundum Atrial Septal Defects in Children

By

Abd El-Moneam, Ahmed Mohammed Gabr*, Ali Abdellatif Afia*, Hassan Saad Abu-Seif*, Amal Mahmoud El-Sisi, Tarek kotb El-Sayad***

Department of Pediatrics - Faculty of Medicine - Al-Azhar University*, Cairo University**

Corresponding author: Abd El-Moneam Ahmed Mohammed Gabr

Mobile: 01069564250, Email: drabdo75@gmail.com

ABSTRACT

Introduction: *Atrial septal defects (ASD) are a common congenital heart disease which causes increased volume overload of the right side of the heart that leads to impairment of LV performance. LV torsion is a three dimensional (3D) performance, so it cannot be assessed accurately by the 2D speckle tracking method.*

Aim of the work: *The purpose of this study was to evaluate left ventricular (LV) rotational & torsional deformation in large ASD patients undergoing transcatheter ASD device closure using 4D speckle tracking Imaging (STI).*

Methods: *All patients who underwent transcatheter device closure of large ostium secundum ASD were included in the study. We assessed LV torsion in large ostium secundum ASD patients pre and post device closure by using 4D speckle tracking echocardiography.*

Results: *A total of 20 patients with large ostium secundum ASD (11 females and 9 males) were included in this study. The mean age was 6.1± 3.5 years and the mean ASD size was 17.95 ± 5.45 mm. LV peak basal clockwise rotation improved significantly in post transcatheter closure (-6.96 ± 2.65˚ before vs. -10.32 ± 4.11˚after closure, P=0.005), and shortened time to peak clockwise rotation (345.15 ± 124.72 ms before vs. 282.25 ± 82.96 ms after closure, P = 0.021). There was no significant difference in apical rotational parameters including peak counterclockwise rotation (4.82 ± 3.44˚ before vs. 6.16 ± 3.38˚ after closure) and time to the peak (250.05 ± 69.17 ms before vs 252.45 ± 60.06 ms after closure (P >0.05 for both). LV twist (11.39 ± 3.81˚ before vs. 17.56 ± 7.18 ˚after closure, P = 0.001) and torsion (2.13 ± 0.79˚/cm before vs. 3.07 ± 1.27 ˚/cm after closer, P = 0.010) were significantly improved in* *patients with large ASD after the device closure, mainly as the result of improvement of LV basal rotation.*

Conclusion: *After large ASD device closure there is increased peak LV twisting and torsion that were mainly attributed to the improved peak systolic clockwise basal rotation while the apical rotation remained unchanged.*

INTRODUCTION

Transcatheter device closure, an attractive alternative to cardiac surgery, has been increasingly performed and was offered as a primary therapy for the secundum atrial septal defect **(Ermis et al., 2015)**. Left ventricular (LV) function and exercise tolerance have been shown to improve in patients undergoing percutaneous ASD closure **(Brochu et al., 2002)**.

Currently, clinical research in cardiac mechanics is moving from short- and long-axis LV function and ejection fraction to three dimensional ventricular deformation studies including LV torsion which plays an important role for both LV systolic and diastolic function **(Buckberg et al., 2004)**. In a recent study, LV systolic twist was found to be significantly reduced in patients with ASD mainly due to the heterogenous basal rotation **(Dong et al., 2009)**. The recent development of 4-dimensional ultrasound speckle tracking imaging (STI) has allowed LV torsional deformation to be evaluated noninvasively in a variety of patient populations **(Baur et al., 2008)**.

The accuracy of this novel technique has been validated with tagged magnetic resonance imaging **(Helle-Valle et al., 2005)**.

AIM OF THE WORK

The aim of this study was to investigate LV torsion deformation in large ASD patients undergoing transcatheter device closure using 4D speckle tracking to evaluate the acute effects of transcatheter large ASD closure on LV twist and torsion (as important indicators of LV function).

PATIENT AND METHODS

Patients:

A total of 20 patients (6.1± 3.5 years, 9 males) scheduled for percutaneous closure of large ASD were enrolled in the study. All patients were prospectively included over the period from November 2016 to August 2018.

Inclusion criteria:

Inclusion criteria included clinically stable patients, age <18 years, hemodynamically significant Secundum ASD with a left-to-right shunt, ASD diameter ≥15 mm/m2, Presence of 4mm or more septal rims other than the aortic rim which may be deficient and evidence of right ventricular volume overload (RV & RA dilation).

Exclusion criteria:

Patients were excluded if they were clinically unstable, were not in sinus rhythm at the time of echocardiographic examination, Sinus venosus and primum ASD types, ASD <15mm/m2, ASD associated with complex congenital heart disease or severe Irreversible pulmonary hypertension.

Ethical Consideration:

1. A written informed consent was obtained from the legal guardians of the patients.
2. An approval by the local ethical committee was obtained before the study.
3. The authors declared no potential conflicts of interest with respect to the research, authorship and/ or publication of this article.
4. All the data of the patients and results of the study are confidential and the parents of the patients have the right to keep it.
5. The legal guardians of the patients have the right to withdraw from the study at any time.

Financial disclosure/funding:

The authors received no financial support for the research, authorship and/ or publication of this article.

Methods:

All patients with large ASD were prospectively included over the period from November 2016 to August 2018 were studied along the following scheme before and 1-day after transcatheter device closure of the defect.

A) History and clinical examination: history of recurrent respiratory infections, clinical evidence of cardiomegaly and signs of pulmonary hypertension.

B) Twelve lead surface electrocardiogram: for evaluation of rate, rhythm and chamber enlargement.

C) Plain Chest x ray: to detect cardiomegaly and increased pulmonary vascular markings.

D) Transthoracic Echo-Doppler study: was done before and one day after transcatheter device closure using Philips EPIQ 7 C ultrasound system with X5-1, S8-3, or X7-2 broadband phasedarray transducers, depending on the age of the patient.

a) Full 2D transthoracic echocardiography:

Visualization of the atrial septum from multiple veiws (subcostal, bicaval, apical four chamber, parasternal short axis) to assess the size, shape, number and location as well as the relation to the surrounding structures particular care to superior vena cava, inferior vena cava, the pulmonary veins and the coronary sinus.

b) Using 2D M-mode to assess:

1. Left ventricular (LV) dimensions and wall thicknesses.
2. Left ventricular Ejection Fraction (EF); according to the recommendations of the American Society of Echocardiography **(Lang et al., 2015)**.
3. Mitral annular plane systolic excursion (MAPSE).
4. Tricuspid annular plane systolic excursion (TAPSE).

c) Using colour-flow and continuous wave (CW) Doppler images to:

1. Detect and assess severity of MR if present.
2. Systolic pressure of the pulmonary artery.
3. Pulsed Wave Doppler (PWD) Imaging: Mitral and tricuspid inflow patterns were recorded from the apical four-chamber view with the pulsed wave Doppler. Early (E) and late (A) transvalvular inflow velocities, the ratio of early-to-late peak velocities (E/A) were obtained.

E): Tissue Doppler Imaging (TDI): Tissue Doppler imaging was performed using Philips EPIQ 7 ultrasound scanner, and general data were obtained mostly from four-chamber view. TDI annular velocities during systole, early relaxation (Ea), and atrial systole (Aa) have been possessed from LV & RV lateral walls and the interventricular septum at the basal site in the apical 4 chamber veiw. Calculation of the global myocardial performance index (MPI) (Tei index) by PW-TDI interval measurements was performed within one cardiac cycle. The Tei index was calculated (MPI of the RV using TDI at tricuspid annulus, for LV using TDI at the lateral mitral annulus.

F) Trans eosophageal Echocardiograghy: TEE was performed after endotracheal intubation and assisted ventilation under general anesthesia. The maximal diameter of the defect was measured using atrial end-diastolic frames in 0, 45, 90 and 135 degrees.

G) Percutaneous ASD closure procedure: was performed using multiple types of devices (Amplatzer, Hyperion, Occlutech, Memopart &Cocoon). Device size was determined by adding 2-4 mm to the largest ASD diameter.

H) 2D Speckle tracking Echocardiography: Data sets were acquired using a four heart beats acquisition setting. 2DSTE strain analysis was performed in multiple views (apical four-chamber, three chamber, two-chamber, and parasternal short axis at basal, papillary and apical levels) to assess LV regional strains and then global longitudinal strain (GLS) and global circumferential strain (GCS) were extracted by bulls eye display by averaging the peak strain values of 16 regional segments. Strain curves were extracted from the grayscale images by using QLAB 2D (Philips Medical Systems).

I) Three-Dimensional Echocardiography: Three-dimensional full volume images to obtain the entire left ventricle in the apical four-chamber view were acquired after the two-dimensional echocardiographic study **(Zhang et al., 2016)**.

J) 4D Speckle tracking Echocardiography: Offline 4D STE analysis was performed using software for echocardiographic quantification (4D LV-analysis 3.0; Tom Tec Imaging Systems, Unterschleissheim, Germany). The 3D data sets were displayed as multi-planar reconstruction images corresponding to four tiles containing three standard long axis (LAX) views (apical four chamber, apical three chamber, and apical 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 multi-planar 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 **(Zhang et al., 2016)**.

Analysis of twist mechanics: Counterclockwise LV rotation as viewed from the apex was expressed as a positive value, whereas a clockwise rotation was denoted as a negative value. LV twist was defined as the net difference between the basal and apical rotation angles (LV twist = apical LV rotation–basal LV rotation). LV torsion was calculated as the net LV twist normalized with respect to ventricular end diastolic (ED) longitudinal length between the LV apex and the mitral plane (LV torsion (°/cm) = LV twist /ED length) **(Zhang et al., 2016)**.

Statistical analysis of data: The collected data were revised, organized, tabulated then were fed to the computer and statistically analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp) Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level. We used Paired t-test for normally distributed quantitative variables, to compare between two periods and Wilcoxon signed ranks test for abnormally distributed quantitative variables, to compare between two periods. For all statistical tests, P value of < 0.05 was considered significant and $P < 0.01$ is considered highly statistically significant result.

RESULTS

Table (1): Descriptive analysis of the studied cases according to demographic data

	Range	Mean ± SD.	Median
Age (years)	2.0 – 14.0	6.12 ± 3.55	4.60
Weight (Kg)	12.0 – 50.0	20.43 ± 10.44	15.75
Length (cm)	83.0 – 155.0	108.0 ± 19.86	103.0
BSA (m2)	0.52 – 1.30	0.72 ± 0.20	0.64
ASD size (mm)	12.0 – 35.0	17.95 ± 5.45	17.0
ASD device size (mm)	13.0 - 38.0	21.25 ± 5.50	20.0
ASD/BSA ratio	15.56 – 36.92	25.7±6.46	26.18

Table (2): Comparison between 2D Echo before and after closure

	Before	After	t	p
LVEDD (cm) (Mean ± SD)	2.92 ± 0.26	3.26 ± 0.55	2.772*	0.012*
LVESD (cm) (Mean ± SD)	1.95 ± 0.23	1.81 ± 0.33	1.908	0.072
EF (%) (Mean ± SD)	66.72 ± 5.05	70.69 ± 8.02	2.294*	0.033*
FS (%) (Mean ± SD)	35.02 ± 2.91	38.42 ± 6.81	2.130*	0.046*

There was a significant increase of the post-procedure LVEDD 24 hrs after closure but, there was no meaningful difference between the pre- and post-procedural LVESD values. Overall, the LVEF significantly increased 24 h after the septal occlusion.

Table (3): Comparison between Pulsed Doppler MV before and after closure (n= 20)

	Before	After	t	p
E wave (Mean ± SD)	88.79 ± 14.23	99.85 ± 18.35	2.736*	0.013*
A wave (Mean ±SD)	53.73 ± 11.96	54.74 ± 11.59	0.366	0.718
E/A ratio (Mean ± SD)	1.68 ± 0.29	1.86 ± 0.30	2.219*	0.039*

LV tissue annular velocity E' (early diastolic) was significantly (P= 0.008) reduced after device closure. LV tissue Doppler MPI values were considerably reduced on the first day after closure.

Table (4): Comparison between tissue Doppler (LV) before and after closure

	Before	After	t	p
E ' wave (cm/sec) (Mean ± SD)	15.41 ± 2.53	13.29 ± 3.20	2.975	0.008*
A' wave (cm/sec) (Mean ± SD)	6.97 ± 1.58	6.89 ± 1.49	0.176	0.862
S' wave (cm/sec) (Mean ± SD)	8.53 ± 1.94	9.54 ± 3.33	1.355	0.191
LV MPI (Mean ± SD)	0.41 ± 0.06	0.38 ± 0.06	2.282	0.034*

Table (5): Comparison between Pulsed Doppler TV before and afterclosure

	Before	After	t	P
E wave (Mean ± SD)	91.23 ± 21.41	67.90 ± 10.80	5.362*	<0.001*
A wave (Mean ±SD)	55.76 ± 17.14	47.98 ± 10.44	2.792*	0.012*
E/A ratio (Mean ± SD)	1.67 ± 0.38	1.44 ± 0.18	2.835	0.011*

Tricuspid valve inflow pulsed Doppler E (early diastolic) wave and the ratio of E/A waves were significantly decreased after ASD closure ($p<0.05$).

Table (6): Comparison between TAPSE and MAPSE before and after closure

	Before	After	t	P
TAPSE (mm) (Mean ± SD)	22.95 ± 4.96	20.15 ± 4.37	3.417*	0.003*
MAPSE (mm) (Mean ± SD)	15.30 ± 2.85	17.55 ± 2.01	2.228*	0.026*

Tricuspid annular plane systolic excursion (TAPSE) was reduced significantly ($P = 0.003$) post device closure.

MAPSE (mitral annular plane systolic excursion) values showed a statistically significant increase in MAPSE on the first day ($p<0.05$) post-procedure when compared to pre-procedure values.

Table (7): Comparison between before and after closure according to tissue Doppler (RV ant. Wall)

	Before	After	t	P
E ' wave (cm/sec) Mean ± SD	18.40 ± 4.08	15.13 ± 4.11	4.572*	<0.001*
A' wave (cm/sec) Mean ± SD	12.09 ± 3.41	8.80 ± 2.22	4.636*	<0.001*
S' wave (cm/sec) Mean ± SD	12.59 ± 1.78	10.85 ± 2.09	3.154*	0.005*
RV MPI Mean ± SD	0.44 ± 0.05	0.47 ± 0.05	1.442	0.166

RV tissue annular velocities E’ (early diastolic), A’ (late diastolic) and S (systolic) waves were reduced significantly following the closure, respectively.

RV tissue Doppler MPI values slightly increased after the first post procedure day compared to the pre-procedure values (p <0.001).

LV global and regional circumferential strain were improved significantly after closure while Longitudinal LV (global and regional) strain showed no significant change between pre and post transcatheter closure.

RV longitudinal strain and RV end-diastolic dimensions were significantly reduced in post ASD device closure.

Table (8): Comparison between 4D RV global analysis before and after closure

	Before	After	p
RVEDV (ml) (Mean ± SD)	47.67 ± 27.83	38.9 ± 18.29	0.017*
RVESV (ml) (Mean ± SD)	37.03 ± 16.03	40.86 ± 21.17	0.351
RVSV (ml) (Mean ± SD)	25.36 ± 13.61	24.64 ± 8.14	0.401
RV EF (%) (Mean ± SD)	48.65 ± 11.27	43.51 ± 8.63	0.029
RVLS (%) (Septum) (Mean ± SD)	-15.84 ± 4.88	-16.12 ± 4.79	0.827
RVLS (%) (free wall) (Mean ± SD)	-23.27 ± 6.44	-20.63 ± 5.74	0.020*

Table (9): Comparison between 4D global LV Analysis before and after closure

	Before	After	p
LVEDV (ml) (Mean ± SD)	35.06 ± 10.51	41.33 ± 15.85	0.023*
LVESV(ml) (Mean ± SD)	15.46 ± 6.16	17.32 ± 10.55	0.360
LVSV (ml) (Mean ± SD)	21.09 ± 7.48	25.65 ± 11.72	0.010*
LVEF (%) (Mean ± SD)	58.12 ± 8.16	62.53 ± 8.89	0.016*
LV Mass (g) (Mean ± SD)	48.10 ± 20.09	54.05 ± 29.34	0.116
LVGLS (%) (Mean ± SD)	-20.21 ± 3.90	-22.13 ± 4.64	0.099
LVGCS (%) (Mean ± SD)	-22.90 ± 6.92	-28.11 ± 7.93	<0.001*

There was no significant difference in apical rotational parameters including peak counterclockwise rotation and time to the peak after closure (P >0.05 for both). On the other hand, there was significant improvement of basal peak clockwise rotation, and shortened time to peak clockwise rotation after closure, P <0.05).

LV twist and torsion were significantly improved after the device closure mainly as the result of improvement of LV basal rotation.

Table (10): Comparison between apical rotation, Basal rotation, twist and torsion before and after closure

		Before	After	t	p
Apical Rotation	**Peak CCW Rotation (°)**				
	Mean ± SD	4.82 ± 3.44	6.16 ± 3.38	1.581	0.130
	T2P (ms) (Mean ± SD)	250.05 ± 69.17	252.45 ± 60.06	0.132	0.897
Basal Rotation	**Peak CW Rotation (°)**				
	Mean ± SD	-6.96 ± 2.65	-10.32 ± 4.11	3.192*	0.005*
	T2P (ms) (Mean ± SD)	345.15 ± 124.72	282.25 ± 82.96	2.528*	0.021*
LV Twist	**Peak Twist (°)**				
	Mean ± SD	11.39 ± 3.81	17.56 ± 7.18	3.828*	0.001*
	T2P (ms) (Mean ± SD)	325.60 ± 131.42	275.85 ± 105.81	3.067*	0.006*
	LV Torsion	2.13 ± 0.79	3.07 ±	Z=	0.010*

	(°/cm) Mean ± SD		1.27	2.577*	

DISCUSSION

Large ASD was defined as an echocardiographic diameter ≥15 mm/m2 in children **(Vitarelli et al., 2012)**. It has been demonstrated that right ventricular volume overload is associated with an impairment of LV performance **(Dong et al., 2009)**. This ventricular

Adverse ventricular interdependence associated with right ventricular volume overload was previously described as "Bernheim effect", in which the interventricular septum bulges into the left ventricular cavity and leads to impairment of left ventricular filling. Hence, improvement in left ventricular form and function seen in patients after closure can be explained by improvement in left ventricular filling **(Balcı et al., 2015)**.

The assessment of ventricular function following percutaneous ASD closure is complicated by the alteration to loading conditions caused by the elimination of intracardiac shunting **(Agha et al., 2015)**.

An increase in LVEDd with no change in the LVESd was

dysfunction mainly results from the mechanical disadvantage of a noncircular short-axis configuration over radial function and can be reversed after elimination of the RV volume overload by transcatheter closure of ASD **(Balcı et al., 2015)**.

seen in our study, also, left ventricular EF improved 1 day after ASD device closure. These results are similar to results reported in other studies **(Romanelli et al., 2014** and **Dong et al., 2009)**.

Many previous studies showed left ventricular (LV) size improvement by echocardiographic assessment within 24 hours following percutaneous closure **(Kaya et al., 2010)**.

In contrast to our results, a small number of studies have discussed the incidence of early LV dysfunction following device placement in adults. Several case reports have discussed early ventricular dysfunction following device closure in patients with known restrictive LV physiology **(Rao and Lorch 2010)**.

Our study showed that mitral valve inflow pulsed doppler E (early diastolic) wave and the ratio of E/A waves were significantly increased after ASD closure. This finding is consistent with **(Ermis et al., 2015)** which showed an immediate increase in mitral inflow following ASD closure. Pulmonary venous flow decreases, but the removal of the septal defect leads to increased mitral inflow and alteration of LV hemodynamics.

Tricuspid valve inflow pulsed Doppler E (early diastolic) wave and the ratio of E/A waves were significantly decreased after ASD closure. Similar results were found by **(Chen et al., 2015)** which mentioned that peak blood flow velocity at the tricuspid valve orifice were reduced significantly after the procedure. This can be explained by rapid decrease of right heart volume load after closure of left to right shunt.

Deformation imaging is a promising technique to assess regional and global myocardial function in children. STE-derived and TDI-derived deformation measurements were both feasible in children, but the speckle-tracking techniques are more user friendly and less time intensive **(Koopman et al., 2010)**.

Using TDI, our study revealed that LV tissue annular velocity E' (early diastolic) was significantly reduced after device closure. Similar result was reported by **(Razak et al., 2018)**. Recent observations suggest that mitral annular early diastolic velocity measured by tissue Doppler imaging is available as a preload independent index of left ventricular relaxation **(Nakai et al., 2006)**.

The present study revealed a significant reduction of Tissue Doppler velocities of RV systolic phase (s'), early (e') and late (a') diastolic phases. The velocity changes represented a response to altered left and right ventricular loading conditions. Also our study revealed that RVEDV decreased significantly after ASD closure. Our data is supported by previous studies showing immediate significant remodeling of cardiac geometry early after closure. **(Chen et al., 2015)** reported a decrease in the RV end-diastolic volume during a median follow-up period of 6 months after ASD closure.

Similarly, RV remodeling and early cardiac geometric change has been documented in the early stage following percutaneous ASD closure **(Popović et al., 2011)**.

The MPI is a proven index to assess the global evaluation of right ventricular systolic and diastolic functions **(Balcı et al., 2015)**. We found that LV tissue doppler MPI values were considerably reduced on the first day after closure. This result agrees with **(Agha at al., 2015)**. This improvement may be due to the restoration of LV compression and the increase in left ventricular filling **(Wu et al., 2007)**.

RV tissue Doppler MPI values slightly increased after the first post-procedure day compared to the pre-procedure values (p<0.001). This result agrees with **(Balci et al., 2015)** which demonstrated that right ventricular MPI was initially increased shortly after ASD device closure then significantly decreased during follow-up in this study.

Similar to our results, **(Ağaç et al., 2012)**, demonstrated that following ASD closure, the long-axis RV function parameter TAPSE decreased after closure.

Using 4D speckle tracking, our study revealed that LV circumferential strain of basal and apical levels significantly increased after ASD closure in response to acute change in loading condition. This result is accordant with **(Razak et al., 2018** and **Dong et al., 2009)** which mentioned that circumferential strain was increased significantly 24 hours after ASD closure, thus it can be used as an indicator of LV response to normalized loading conditions

According to our study results, LV longitudinal strain was not affected in the early after ASD closure which agreed with **(Razak et al., 2018** and **Cakal et al., 2015)**.

Rotation and twist are concepts that first became familiar to echocardiographers with the appearance of speckle tracking echocardiography. Three-dimensional speckle tracking echocardiography, not two-dimensional speckle tracking echocardiography, should be used to avoid the effect of the through plane motion **(Nakatani, 2011)**.

LV torsional deformation plays an important role for both LV systolic and diastolic function. LV systolic twist was significantly reduced in patients with ASD mainly due to the

The present study elucidated LV torsional deformation in ASD patients pre and post transcatheter device closure. Using 4D STI method, we observed that transcatheter closure of large secundum ASD was associated with an increased LV systolic twist and this effect was mainly attributed to the improvement of LV basal but not apical rotation.

4D STI analysis in our study showed that LV basal rotation improved significantly while apical rotation remained unchanged after ASD closure.

As previous studies have consistently demonstrated, the normal LV performs a short-duration counterclockwise rotation that gradually changed into a more substantial clockwise rotation at the base **(Nakai et al., 2006)**. However, **(Dong et al., 2009)** showed a singularly reduced and delayed clockwise rotation following an abnormally enhanced and extended initial counterclockwise rotation at the basal level in patients with ASD. After device closure, the basal rotation was improved significantly and its pattern became accordant with

heterogenous basal rotation **(Dong et al., 2009)**.

basal rotational characteristics in normal subjects.

Since the LV twist was defined as the LV apical rotation relative to the basal rotation, and the basal rotation was improved after ASD closure, it is not surprising to observe a significantly increased LV twist after ASD closure in our study. Similar to our results, **(Dong et al., 2009)** demonstrated a significant increase in LV systolic twist after the procedure due to increased basal clockwise rotation while apical counter clockwise remained unchanged.

The present work also revealed that LV torsion has improved shortly (24 hours) after device closure. These findings are in accordance with **(Razak et al., 2018)** which stated that LV torsion has improved immediately after device closure based on loading conditions rather than ventricular remodeling.

As the LV torsional deformation is thought to decrease oxygen demand during systole, the increased LV twist as well as the improved basal rotation may play a role in the improvement of LV systolic performance after ASD device closure **(Dong et al., 2009)**.

Longitudinal RV free wall strain can provide a reliable RV longitudinal quantification because RV contraction is more based on longitudinal shortening. RV function is a very important prognostic factor in ASD patients because this chamber has to tolerate chronic volume overload **(Moradian et al., 2018)**.

In ASD patients, RV lateral longitudinal strain is higher and RV septal strain is similar (or slightly higher) compared with healthy controls **(Eroglu et al., 2013)**. Our study showed that RV Lateral longitudinal strain, RVEF and TAPSE were significantly reduced in post ASD device closure. This result in accordance with **(Vitarelli et al., 2012)** which evaluated 39 patients before and 6 months after closure, and demonstrated that 3D RVEF and global and regional RV longitudinal strain were decreased meaningfully after closure. This can be explained by delayed remodeling of right ventricular mass which occur gradually in the face of acute right heart volume reduction.

CONCLUSION

The assessment of left ventricular twisting and torsional deformation was practically realistic using the non-invasive 4D speckle tracking imaging method. Left ventricular twisting and torsion was increased after transcatheter device closure of large ASD. This improvement was mainly due to the improved LV basal clockwise rotation rather than the unchanged apical counterclockwise rotation.

REFERENCES

1. **Ağaç, M. T., Akyüz, A. R., Acar, Z., Akdemir, R., Korkmaz, L., Kırış, A., ... & Çelik, Ş. (2012).** Evaluation of right ventricular function in early period following transcatheter closure of atrial septal defect. Echocardiography, 29(3), 358-362.
2. **Agha, H. M., El-Saiedi, S. A., Shaltout, M. F., Hamza, H. S., Nassar, H. H., Abdel-aziz, D. M., & El Tantawy, A. E. (2015).** Incomplete RV Remodeling After Transcatheter ASD Closure in Pediatric Age. Pediatric cardiology, 36(7), 1523-1531.
3. **Balcı, K. G., Balcı, M. M., Aksoy, M. M., Yılmaz, S., Aytürk, M., Doğan, M., Aytürk M & Akdemir, R. (2015).** Remodeling process in right and left ventricle after percutaneous atrial septal defect closure in adult patients. Turk Kardiyoloji Dernegi arsivi: Turk Kardiyoloji Derneginin yayin organidir, 43(3), 250-258.

4. **Baur, L. H. B. (2008).** Strain and strain rate imaging: a promising tool for evaluation of ventricular function. The international journal of cardiovascular imaging, 24(5), 493-494.
5. **Brochu, M. C., Baril, J. F., Dore, A., Juneau, M., De Guise, P., & Mercier, L. A. (2002).** Improvement in exercise capacity in asymptomatic and mildly symptomatic adults after atrial septal defect percutaneous closure. Circulation, 106(14), 1821-1826..
6. **Buckberg, G. D., Weisfeldt, M. L., Ballester, M., Beyar, R., Burkhoff, D., Coghlan, H. C., ... & Ingels, N. B. (2004).** Left ventricular form and function: scientific priorities and strategic planning for development of new views of disease. Circulation, 110(14), e333-e336.
7. **Cakal, S., Eroglu, E., Baydar, O., Cakal, B., Yazicioglu, M. V., Bulut, M., ... & Avci, A. (2015). Two-Dimensional Strain and Strain Rate Imaging of the Left Atrium and Left Ventricle in Adult Patients with Atrial Septal Defects before and after the Later Stage of Percutaneous Device Closure. Echocardiography, 32(3), 470-474.**
8. **Chen, Q., Sun, X. D., Cao, H., Zhang, G. C., Chen, L. W., & Hu, Y. N. (2015).** Echocardiographic Evaluation of Changes in Cardiac Hemodynamics and Loading Conditions after Transthoracic Minimally Invasive Device Closure of Atrial Septal Defect. PloS one, 10(7), e0128475. doi:10.1371/journal.pone.0128475**.**
9. **Chen, L., Bai, Y., Wang, F. Y., Zhang, Z. G., Shan, X. H., Chen, T., ... & Qin, Y. W. (2015).** Transcatheter closure of atrial septal defects improves cardiac remodeling and function of adult patients with permanent atrial fibrillation. Chinese medical journal, 128(6), 780.
10. **Dong, L., Zhang, F., Shu, X., Zhou, D., Guan, L., Pan, C., & Chen, H. (2009).** Left ventricular torsional deformation in patients undergoing transcatheter closure of secundum atrial septal defect. The international journal of cardiovascular imaging, 25(5), 479-486.
11. **Ermis, P., Franklin, W., Mulukutla, V., Parekh, D., & Ing, F. (2015).** Left ventricular hemodynamic changes and clinical outcomes after transcatheter atrial septal defect closure in adults. Congenital heart disease, 10(2), E48-E53
12. **Eroglu, E., Cakal, S. D., Cakal, B., Dundar, C., Alici, G., Ozkan, B., ... & Esen, A. M. (2013).** Time course of right ventricular remodeling after percutaneous atrial septal defect closure: assessment of regional deformation properties with two-dimensional strain and strain rate imaging. Echocardiography, 30(3), 324-330.
13. **Gade, C. L., Bergman, G., Naidu, S., Weinsaft, J. W., Callister, T. Q., & Min, J. K. (2007).** Comprehensive evaluation of atrial septal defects in individuals undergoing percutaneous repair by 64-detector row computed tomography. The international journal of cardiovascular imaging, 23(3), 397-404.
14. **Helle-Valle, T., Crosby, J., Edvardsen, T., Lyseggen, E., Amundsen, B. H., Smith, H. J., ... & Smiseth, O. A. (2005).** New noninvasive method for assessment of left ventricular rotation: speckle tracking echocardiography. Circulation, 112(20), 3149-3156.
15. **Kaya, M. G., Baykan, A., Dogan, A., Inanc, T., Gunebakmaz, O., Dogdu, O., ... & Narin, N. (2010).** Intermediate-term effects of transcatheter secundum atrial septal defect closure on cardiac remodeling in children and adults. Pediatric cardiology, 31(4), 474-482.
16. **Koopman, L. P., Slorach, C., Hui, W., Manlhiot, C., McCrindle, B. W., Friedberg, M. K., ... & Mertens, L. (2010).** Comparison between different speckle tracking and color tissue Doppler techniques to measure global and regional myocardial deformation in

children. Journal of the American Society of Echocardiography, 23(9), 919-928.

17. **Lang, R. M., Badano, L. P., Mor-Avi, V., Afilalo, J., Armstrong, A., Ernande, L., ... & Lancellotti, P. (2015).** Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. European Heart Journal-Cardiovascular Imaging, 16(3), 233-271.

18. **Moon, M. R., Ingels, N. B., Daughters, G. T., Stinson, E. B., Hansen, D. E., & Miller, D. C. (1994).** Alterations in left ventricular twist mechanics with inotropic stimulation and volume loading in human subjects. Circulation, 89(1), 142-150.

19. **Moradian, M., Daneshamooz, H., Shojaeifard, M., Ghadrdoost, B., Langeroudi, H. M., & Khorgami, M. R. (2018).** Echocardiographic right ventricular deformation indices before and after atrial septal defect closure: A scomparison between device and surgical closure. Research in Cardiovascular Medicine, 7(2), 92.

20. **Nakai, H., Takeuchi, M., Nishikage, T., Kokumai, M., Otani, S., & Lang, R. M. (2006).** Effect of aging on twist-displacement loop by 2-dimensional speckle tracking imaging. Journal of the American Society of Echocardiography, 19(7), 880-885.

21. **Nakatani, S. (2011).** Left ventricular rotation and twist: why should we learn?. Journal of cardiovascular ultrasound, 19(1), 1-6.

22. **Popović, Z. B., Desai, M. Y., Buakhamsri, A., Puntawagkoon, C., Borowski, A., Levine, B. D., ... & Thomas, J. D. (2011).** Predictors of mitral annulus early diastolic velocity: impact of long-axis function, ventricular filling pattern, and relaxation. European Journal of Echocardiography, 12(11), 818-825.

23. **Rao, P. S., & Lorch, S. (2010).** Left ventricular function after percutaneous occlusion of atrial septal defects. Echocardiography, 27(3), 351-353.

24. **Razak, A., Al Hajri, M. S. M., Shetty, K. R., & Nayak, K. (2018).** Left Ventricular Torsion Deformation in Atrial Septal Defect Patients Undergoing Transcatheter Device Closure. International Journal of Cardiovascular Practice, 3(3).

25. **Romanelli, G., Harper, R. W., & Mottram, P. M. (2014).** Transcatheter closure of secundum atrial septal defects: results in patients with large and extreme defects. Heart, Lung and Circulation, 23(2), 127-131

26. **Vitarelli, A., Sardella, G., Di Roma, A., Capotosto, L., De Curtis, G., D'Orazio, S., ... & Bruno, P. (2012).** Assessment of right ventricular function by three-dimensional echocardiography and myocardial strain imaging in adult atrial septal defect before and after percutaneous closure. The international journal of cardiovascular imaging, 28(8), 1905-1916.

27. **Wu, E. T., Akagi, T., Taniguchi, M., Maruo, T., Sakuragi, S., Otsuki, S., ... & Sano, S. (2007).** Differences in right and left ventricular remodeling after transcatheter closure of atrial septal defect among adults. Catheterization and Cardiovascular Interventions, 69(6), 866-871.

28. **Zhang, L., Zhang, J., Han, W., Gao, J., He, L., Yang, Y., ... & Ge, S. (2016).** Three-dimensional rotation, twist and torsion analyses using real-time 3D speckle tracking imaging: feasibility, reproducibility, and normal ranges in pediatric population. PloS one, 11(7), e0158679.

تقييم تعديل دوران البطين الأيسر بواسطة الموجات الصوتية غير التقليدية علي القلب قبل وبعد إغلاق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية في الأطفال

عبد المنعم أحمد محمد جبر*- علي عبداللطيف عافية* - حسن سعد أبوسيف* - أمل محمود السيسي - طارق قطب الصياد***

قسم طب الأطفال – كلية الطب – جامعة الأزهر* - جامعة القاهرة**

المقدمة: يعتبر ثقب الحاجز الأذيني من أشهرعيوب القلب الخلقية والذي يؤدي الي اتساع البطين الأيمن مما يؤثر بالسلب أيضا علي آداء البطين الأيسر. يعد التواء البطين الأيسر آداء ثلاثي الأبعاد والذي لا يمكن تقييمه بدقة بواسطة التتبع النقطي ثنائي الأبعاد.

الهدف من البحث: تقييم تغير دوران والتواء البطين الأيسر بواسطة التتبع النقطي رباعي الأبعاد لدي الأطفال الذين خضعوا لغلق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية.

الطريقة والأدوات: أجريت هذه الدراسةِ على عشرون طفلا (تسعة ذكور وأحد عشر أنثي) يعانون من ثقب كبير بالحاجز الأذيني من المترددين على عيادة قلب الأطفال بمستشفى أبو الريش الياباني بالقاهرة والذين تتراوح أعُمارهم 2 إلى 14 سَنَة، وبعد أخذ التاريخ المرضى الكامل والفحص السريري الشامل، والأبحاث الطبية والفحوصات بأشعة الصدر ورسم القلب تم عمل موجات صوتية ثنائية ورباعية الأبعاد علي القلب وعمل تتبع نقطي رباعي الأبعاد لتقييم دوران والتفاف البطين الأيسرقبل وبعد غلق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية لجميع الحالات التي اخضعت لهذه الدراسة.

النتائج : خلصت النتائج الي تحسن ذروة دوران قاعدة البطين الأيسر في اتجاه عقارب الساعة وقصر وقت الوصول الي ذروة دوران قاعدة البطين الأيسرمباشرة بعد غلق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية ولم يكن هناك اختلاف ملحوظ في

دوران قمة البطين الأيسر في عكس اتجاه عقارب الساعة أو في وقت الوصول الي ذروة دوران قمة البطين الأيسر عند هؤلاء الأطفال.

وأن هناك تحسن في ذروة التواء البطين الأيسر بشكل ملحوظ مباشرة بعد غلق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية.

الإستنتاج: تحسن ذروة التواء البطين الأيسر بعد غلق ثقب الحاجز الأذيني كبير الحجم عن طريق القسطرة القلبية يعزي أساسا الي تحسن ذروة دوران قاعدة البطين الأيسر في اتجاه عقارب الساعة أثناء الانقباض مما يؤدي الي تحسن الوظيفة الانقباضية للبطين الأيسر.