EVALUATION OF RIGHT VENTRICULAR FUNCTION BEFORE AND AFTER CLOSURE OF ATRIAL SEPTAL DEFECT IN PEDIATRIC PATIENTS

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ABSTRACT

Background: ASD is one of the most common congenital heart defects (CHD). Although surgical closure of secundum type ASD has been considered the standard treatment for many years with very low rate of complication, trans-catheter ASD closure has become an important alternative to surgical repair with an excellent outcome.

Objectives: We aim to evaluate the right and left ventricular functions in children with ASD before and after ASD closure and to compare RV functions between post-surgical versus post trans-catheter ASD closure.

Patients and methods: This study was conducted on 30 children with large atrial septal defect, who underwent successful ASD closure either surgical (20 patients) or trans-catheter device (10 patients)**.** All cases were assessed by; conventional echocardiography, tissue Doppler imaging, deformation imaging and 3- D echocardiography.

Results: Tissue Doppler Imaging (TDI) assessment of systolic functions for tricuspid velocity in cases showed, no significant difference after ASD device closure. The tricuspid E/E` ratio showed significant decrease in ASD patients after device and surgical closure The TAPSE showed significant decrease after ASD closure in both surgical and device closure groups. The RVMPI showed significant decrease after ASD closure in both surgical and device closure groups. Three dimensional (3-D) RV end-diastolic volume, 3-D RV end-systolic volume and 3-D RV EF showed significant decrease after ASD closure either surgical or device closure.

Conclusion: A significant shunt in the secundum ASD affects right and left ventricular sizes, systolic and diastolic functions. Three-dimensional (3D) echocardiography, TDI and deformation imaging are promising tools in estimating RV dysfunction in those cases.

Key Words: right ventricle, atrial septal defect, transthoracic echocardiography, three dimensional echocardiography

INTRODUCTION

An atrial septal defect (ASD) or interatrial communication is one of the most common congenital heart defects (CHD), accounting approximately for 5/10,000 live births and 7–10 % of all congenital heart defects and 30%-33% of defects diagnosed in adults with CHD. [(1)] Ostium secundum defect is the commonest type of ASDs, which occurs as an isolated anomaly in 5 % to 10% of all congenital heart defects. It is more common in females than in males (female/ male ratio of 2:1). About 30% to 50% of children with congenital heart defects have an ASD as part of the cardiac defect. [(2)]

Clinical effects of isolated ASDs are usually related to left-to-right shunting, which, causes volume overloading of the right ventricle and pulmonary circulation, but this is generally well tolerated in infancy and childhood[(3)]. The magnitude of the left-to-right shunt across the ASD depends on the defect size, the relative compliance of the left-sided and right-sided cardiac chambers, and the relative resistance in both the pulmonary and systemic circulation. [(4)]

Infants and young children with an ostium secundum ASD is most often asymptomatic; the lesion may be discovered accidentally during physical examination. Even an extremely large secundum ASD rarely produces clinically evident heart failure in childhood. [(5)]

The echocardiographic evaluation of ASD includes the detection of the size and shape of the septal defects, the rims of tissue surrounding the defect, the degree and direction of shunting, and the changes in size and function of the cardiac chambers and pulmonary circulation pre versus post ASD closure[(6)]**.**

The evaluation of RV function by echocardiography remains difficult due to its complex geometry. Although clinical investigations of the RV have been focused on the use of two- dimensional echocardiography, recent developments in echocardiographic techniques as the three-dimensional echocardiography (3-DE), tissue

Doppler imaging (TDI), strain and strain rate imaging, which are sensitive and noninvasive have enhanced for accurate assessment of RV function.[7]

In this study, we aim to assess the right and left ventricular functions in children with ASD before closure as compared to patients after closure and to compare RV functions in cases post surgical versus post transcatheter device closure. We also aim to explore if the new echocardiographic modalities as tissue Doppler imaging, 3- D echocardiography and strain imaging have an additional value over conventional methods in RV function assessment in ASD pediatric patients.

PATIENTS AND METHODS

The current study is a prospective study included 30 patients diagnosed as isolated large secundum ASD, , aged 2–16 years (mean age of 8.5), including 22 females and 8 males, who had undergone successful surgical or device ASD closure, surgical group = 20 patients and device group = 10 patients. The study was performed in Pediatric Cardiology Unit and Pediatric Echocardiography Laboratory in Zagazig University Children's Hospital during the period between 2011 and 2015. The study protocol was approved by Ethics Committee, Faculty of Medicine, Zagazig University.

Patients in both groups were selected according to the following inclusion criteria: The presence of a large secundum ASD by echocardiography for both groups. A significant left-to- right shunt with a Qp: Qs ratio of 1.5:1. The presence of right ventricular volume overload and shunt related symptoms. Successful percutaneous transcatheter or surgical occlusion and there was no residual shunt, complications, and clinical cardiac dysfunction after procedure. The Exclusion criteria for both groups included: Associated congenital cardiac anomalies requiring surgery or acquired valvular or myocardial disease. Premium ASD or other types of ASD. Partial anomalous pulmonary venous drainage. Abnormal cardiac rhythm. Pulmonary vascular resistance (PVR) of >5 Wood units and/or >2/3 systemic vascular resistance. Contraindication for antiplatelet or anticoagulant therapy. Inability to obtain informed consent.

Methods:

Both groups will be subjected to Proper history, detailed general and cardiac clinical examination, chest X-ray, ECG and Echocardiography study

The echocardiographic examination performed upon ASD patient before closure and repeated after surgical or transcatheter closure.

Echocardiography:

Echocardiographic measurement was carried out according to the recommendation of the American Society of Echocardiography. left ventricular end diastolic (LVED) and left ventricular end systolic (LVES) dimensions, the right ventricular end-diastolic diameter (RVEDD).Evaluation of cardiac valves function and morphology and cardiac septae. Evaluation of conventional RV and LV systolic and diastolic functions. Tricuspid Annular Plane Systolic Excuration (TAPSE). The myocardial performance index (MPI). Tissue Doppler annular velocity imaging measurements. Longitudinal strain and strain rate imaging measurements. Real time-dimensional echocardiography (RT3-DE).

Surgical closure of ASD:

For patients who underwent surgical closure, standard ASD repair under general endotracheal anesthesia was performed. Patients were discharged home after three to five days in the hospital, depending on their clinical condition.

Transcatheter closure of ASD:

Percutaneous closure of the ASD was performed under general or local anesthesia after the measurement of native and balloon-stretched diameters of the defect, the closure procedure was performed using a suitable sized Amplatzer septal occluder (AGA Medical, Golden Valley, MN, USA).

Statistical analysis:

All data were collected, tabulated and statistically analyzed using SPSS 20.0 for windows. Quantitative data were expressed as the mean ± SD & median (range). Continuous data were checked for normality by using Shapiro Walk test.

Independent Student t-test was used to compare two groups of normally distributed data. Mann-Whitney U was used to compare two groups of non normally distributed data. Kraskall Wallis H test was used to compare more than two groups of non normally distributed data. Paired t test was used to compare two dependent groups of normally distributed data. Wilcoxon signed ranks test was used to compare two dependent groups of non-normally distributed data.

All tests were two sided. $p < 0.05$ was considered statistically significant (S), $p < 0.001$ was considered highly statistically significant (HS), and $p \geq 0.05$ was considered non statistically significant (NS).

RESULTS

The study included 30 patients of secundum ASD with mean size of ASD ranging from 12-20 mm.

for the RV dimensions: there is significant decrease in RVEDd and RAd in ASD cases after catheter and surgical closure. The LV dimensions show significant increase in LVEDd diameter in ASD cases after catheter and surgical. The RVEDd/LVEDd show significant decrease in ASD cases after catheter and surgical.

The LV systolic functions (EF %) show significant increase in ASD cases after catheter closure while (FS %). The RV diastolic functions (E, and E/A) are significantly decreased in ASD cases after catheter closure, while A showed no significant difference. TAPSE is significantly decreased in ASD cases after both catheter and surgical closure. There is significant decrease in RV Tei index in ASD cases after both catheter and surgical closure, while the LV Tei index showed no significant difference. Tissue Doppler tricuspid& mitral annular velocities were not significantly different in pre ASD catheter closure than post closure, while the TV E/ E´ ratio are decreased significantly in ASD cases after catheter closure, and the MV E/ E´ ratio are increased significantly in ASD cases after catheter closure.

There is significant decrease in 3D RV (EDV, ESV and EF) in ASD cases after both catheter and surgical closure.

The strain of ant. wall (basal & baso-lateral) and septum (basal. middle, and apical) in ASD cases are significantly decreased after both catheter and surgical closure, while the strain of posterior wall apical and basal are not significantly different in pre closure as compared to post closure.

Tissue Doppler tricuspid annular velocities and TV E/ E´ ratio are decreased significantly in ASD cases after surgical closure, while the A´velocity show no significant difference. Mitral valve E/ E´ ´velocity show no significant difference.

There is no significant difference in strain rate in ASD patients underwent surgical closure as comparing pre closure versus post closure.

Table (1): Comparison between the catheter and surgery group before procedure as regard demographic data, baseline Clinical data , heart rate, ASD size and PSP:

Demographic data	ASD cath group (N=10)	ASD surgery group (N=20)	(Sig.)
Age (years) Mean ± SD	5.60 ± 4.86	6.45±4.23	(NS) *
Sex : Male/Female	2 /8	6 /14	(NS) ‡
Weight (kg) Mean ± SD	21.80 ± 16.16	20.60±10.09	(NS) •
Heart rate (b/m) Mean ± SD	108.40 ± 15.09	99.80 ± 11.27	(S) *
Dyspnea: No. (%)	4 (40%)	12 (60%)	(NS) ‡
Recurrent chest infection: No. (%)	6 (60%)	6 (30%)	(NS) ‡
ASD size(mm) Mean ± SD	12.80±2.77	20.30±6.30	(S) †
PSP Mean ± SD	43.40±5.02	42.00±7.88	(S) *

* One Way ANOVA test. • Kruskall Wallis H test. ‡ Chi-square test. † Independent samples Student's t-test. S: significance.

Table (2): Echocardiographic dimensions, systolic and diastolic conventional echocardiographic functions of RV& LV in ASD patients before versus after catheter and surgical closure:

		ASD patients underwent catheter closure			ASD patients underwent surgical closure		
		Before closure (n= 10) Mean ± SD	After closure (n= 10) Mean± SD	p-value	Before closure (n= 20) Mean ± SD	After closure (n= 20) Mean± SD	p-value
2-D diameters:							
RVEDd(mm)		29.40 ± 4.04	26.40 ± 3.29	0.043*	32.60±5.30	28.10± 3.98	<0.001**
RAd (cm)		3.80 ± 0.76	3.24 ± 0.54	0.043*	3.99±0.69	3.47±0.55	0.001*
LVEDd (mm)		30.40 ± 4.16	37.8 ± 3.98	<0.05*	31±4.78	38.1±4.37	0.01*
LVESd (mm)		17.80 ± 3.49	18.80 ± 3.90	0.13	17.40±3.50	19.90±3.35	0.017*
RVED/LVEDd		0.97 ± 0.12	0.81 ± 0.11	0.043*	1.06±0.17	0.81±0.07	<0.001**
Conventional systolic functions:							
LV	**EF (%)**	71.9±4.18	74.1±3.02	<0.01 *	72.6±4.22	74.30±3.12	<0.05 *
	FS (%)	39.80±2.59	41.40±3.29	0.336	44.50±7.63	42.70±3.68	0.442
RV	**TAPSE (mm)**	26.2±3.12	21.4±4.18	<0.05 *	26.4±3.12	21.90±4.22	<0.05*
Conventional diastolic 2-D Doppler derived velocities:							
RV diastolic function(Tricuspid valve)							
E		1.06±0.22	0.78±0.17	0.043*	1.18±0.26	0.75±0.16	0.001*
A		0.78±0.23	0.71±0.18	0.080	1.08±0.39	0.58±0.18	0.006*
E/A		1.49±0.24	1.18±0.19	0.043*	1.24±0.10	1.32±0.27	0.198
LV diastolic function (Mitral valve)							
E		0.76±0.39	1.03±0.15	0.068	0.95±0.17	0.93±0.19	0.764
A		0.61±0.22	0.80±0.20	0.043	6.07±16.84	0.73±0.24	0.721
E/A		1.47±0.95	1.31±0.26	0.500	1.36±0.23	1.47±0.21	0.764

* Statistically significant from pre-procedure. ** Statistically highly significant from pre-procedure.

Table (3): RV& LV tissue Doppler derived velocities & MPI in ASD patients before versus after cathetere closure and before versus after surgical closure:

Velocities		ASD patients underwent catheter closure			ASD patients underwent surgical closure		
		Before closure (n= 10) Mean ± SD	After closure (n= 10) Mean± SD	p-value	Before closure (n= 20) Mean ± SD	After closure (n= 20) Mean± SD	p-value
Tricuspid annular Tissue Doppler velocities							
RV	**S´**	0.11 ± 0.02	0.12±0.02	0.461	1.98±5.98	0.08±0.03	•0.034*
	E´	0.14±0.03	0.12±0.01	1.000	0.12±0.03	0.10±0.03	§0.030*
	A´	0.12±0.01	0.12±0.01	0.180	0.11±0.04	0.08±0.03	§0.135
	TV E/ E´	8.13±1.06	7.09±1.05	<0.01*	8.88±1.53	7.12±1.02	•<0.05*
Mitral annular Tissue Doppler velocities							
LV	**S´**	0.08±0.02	0.07±0.01	0.131	0.08±0.01	0.07±0.01	§0.052
	E´	0.13±0.02	0.11±0.03	0.066	0.14±0.04	0.13±0.02	§0.385
	A´	0.07±0.01	0.07±0.02	1.000	0.10±0.03	0.08±0.03	•0.281
	MV E/ E´	7.26±1.78	9.80±2.37	0.042*	6.84±1.60	7.31±2.64	•0.799
Tissue Doppler derived myocardial performance index (Tei index)							
RMPI (mm)		0.30±0.09	0.25±0.07	§<0.05*	0.32±0.10	0.26±0.07	§<0.05*
LMPI (mm)		0.35±0.17	0.28±0.10	0.144	0.40±0.12	0.35±0.14	•0.109

§ Paired t-test. • Wilcoxon signed ranks test. p< 0.05 is significant.*Statistically significant from pre procedure.

Table (4): 3-D echocardiography values in ASD patients before versus after cathetere closure and before versus after surgical closure:

3- D		ASD patients underwent catheter closure			ASD patients underwent surgical closure		
		Before closure (n= 10) Mean ± SD	After closure (n= 10) Mean± SD	p-value	Before closure (n= 20) Mean ± SD	After closure (n= 20) Mean± SD	p-value
RV	EDV	71.40±41.94	59.8±35.51	0.042*	79 ± 46	59.1 ± 31.96	<0.005*
	ESV	39.6±22.9	31.8±16.4	<0.05*	38.1 ± 21.35	29.7 ± 19.4	<0.05*
	EF	50.1±13.6	47.9±14.5	<0.01*	50.8 ± 6.36	43.0 ± 6.93	0.011*
LV	EDV	46±17.32	50.0±17.58	0.500	53.7± 25.01	57.6 ± 25.64	0.136
	ESV	22±9.27	21.4±8.11	1.000	28.7 ± 12.30	28.4 ± 11.89	0.774
	EF	53.40±4.83	55.4]±7.77	0.893	47.5 ±5.04	50.1 ± 8.95	0.252

p< 0.05 is significant *Statistically significant from pre-procedure.

Table (5): Longitudinal strain and strain rate of septum, post. wall and anterior wall in ASD patients before versus after cathetere closure and before versus after surgical closure:

		ASD patients underwent catheter closure			ASD patients underwent surgical closure		
		Before closure (n= 10) Mean ± SD	After closure (n= 10) Mean± SD	p-value	Before closure (n= 20) Mean ± SD	After closure (n= 20) Mean± SD	p-value
Strain							
RV(ant .wall)	Basal	24.89±3.65	20.07±3.82	<0.01*	24.69±2.76	21.07±2.65	<0.01*
	Baso-lateral	27.16±2.61	21.53±3.29	<0.05*	26.50±3.37	20.34±2.69	<0.05*
Septum	Basal	25.24±3.75	18.68±4.45	<0.01*	25.41±2.73	18.78±3.45	<0.01*
	Mid	25.26±2.41	17.96±4.64	<0.01*	25.21±2.99	18.36±3.79	<0.01*
	Apical	21.91±3.10	15.14±4.50	<0.01*	22.46±3.75	16.09±4.50	0.001*
Lat. wall	Basal	18.63±4.87	20.80±2.20	0.138	18.33±3.30	19.31±1.07	0.677
	Baso-lateral	18.45±4.87	19.76±3.51	0.686	19.45±2.80	20.87±3.26	0.682
Strain-rate							
RV(ant . wall)	Basal	1.84±0.20	1.83±0.45	0.686	1.85±0.28	1.63±0.27	0.152
	Baso-lateral	2.03±0.30	1.81±0.28	0.345	1.78±0.30	1.58±0.25	0.053
Septum	Basal	1.61±0.44	1.64±0.25	1.000	1.87±0.27	1.73±0.42	0.484
	Mid	1.43±0.27	1.47±0.23	0.500	1.71±0.49	1.59±0.34	0.579
	Apical	1.58±0.42	1.40±0.44	0.345	1.70±0.36	1.47±0.54	0.289
Lat. wall	Basal	1.70±0.56	1.86±0.27	0.225	1.92±0.45	1.72±0.39	0.263
	Baso-lateral	1.58±0.34	1.43±0.29	0.500	1.76±0.46	1.76±0.39	0.986

p< 0.05 is significant. *Statistically significant from pre-procedure.

DISCUSSION

Atrial septal defects (ASDs) are the most common form of congenital heart disease, which constitutes 10% of all congenital heart diseases at birth. The large ASDs is characterized by long-standing left to right shunt which causes chronic right ventricular (RV) volume overload and pulmonary vascular changes resulting in RV pressure overload that leads to right chambers enlargement, dysfunction, and finally to chronic heart failure.[(8)]

Thus, closure of ASD leads to symptom's improvement, anatomical, geometrical, and functional improvement of right and left heart chambers**.** [(9)]

Although surgical closure of secundum type ASD has been considered the standard treatment for more than long years with very low rate of complication, trans-catheter ASD closure has become an important alternative to surgical repair with an excellent outcome. [(9)]

Quantitative assessment of right ventricular function is still challenging due to its complex anatomy and thin wall structure that limits the use of the traditional methods used to assess LV function. [(10)]

So, recent echocardiographic techniques have enhanced the ability to assess RV systolic and diastolic functions accurately, which have been evaluated using several parameters including : RV myocardial performance index (RMPI); "The tie index, tricuspid annular plane systolic excursion (TAPSE), Tissue Doppler Tricuspid annular velocities, 3- D echocardiography, longitudinal strain and strain rate[(11)].

In our study, we evaluated echocardiographic changes in the left and right heart in children with secundum ASD before& three- month after percutaneous or surgical closure of ASD. We compared echocardiographic changes after ASD device closure with those after ASD surgical closure.

In our study, we found that, there was a significant reduction in all right sided dimensions including the RVEDd, right atrial diameter, RV/LVEDd ratio (regarded as an indicator of cardiac geometry), after ASD closure in both surgical and percutaneouse, groups as compared to the prec-losure.

This is in agreement with other authors; **Balcı et al.** [(12)] reported reductions in RVEDD, right atrial diameter, and RVEDD/LVEDD ratio three months post percutaneous ASD closure. **Chen et al.** [(13)] observed that the right ventricular volume load and various measures of the right heart system reduced gradually at 3 months and at 1 year after the procedure as compared with the preoperative data.

In contrast to our study considering surgical closure, previous study as **Ning et al.** [(14)] have shown that persistent RV enlargement continued in approximately 50% of both adults and children after surgical repair despite elimination of the right heart volume over load. This could be explained by a few mechanisms including myocardial changes due to long-term volume load, functional abnormalities due to cardiopulmonary bypass, and geometric modifications of the heart due to opening of the pericardium.

The pulmonary vasculature normally accommodates the increased volume of flow secondary to ASD without a significant increase in PA pressure. [(15)] With continued RV volume overload and increased PA flow over time, a small percentage of patients will develop pulmonary hypertension, with an even smaller percentage developing irreversible pulmonary vascular disease. The normal peak RV systolic pressure should be less than 30–35 mmHg. [(6)]

In the current study, we found that, the mean PASP decreased significantly in ASD patients after ASD closure as compared to pre closure. This is in agreement with **Chen et al.** [(13)] who reported similar results, and explained the above findings as after ASD closure, the real-time right-to-left shunt disappeared, the diastolic blood flow velocity at the tricuspid valve orifice and the systolic blood flow velocity at the pulmonary valve orifice decreased, and hemodynamic abnormalities were corrected. One week after the procedure, the systolic blood flow velocity of the pulmonary artery and the diastolic blood flow velocity in the tricuspid valve were significantly reduced.

As regarding the left side, in our study, we observed that there was a significant increase in the LVEDd after ASD closure both surgical and transathetere, but the LVESd and left atrial diameter did not show significant changes.

This is in accordance with other publications, as **Balcı et al.** [(12)] **and Chen et al.**[(13)]. They reported similar findings, that the

LVEDd showed significant increase with no different changes in the LVESd and LA diameter in ASD patients post closure when compared to pre closure group.

Left ventricular systolic function was assessed by the ejection fraction (EF) and the shortening fraction (SF) obtained by M-mode. [17]

In the current study, the left ventricular EF increased significantly in ASD patients post closure as compared with pre closure in both surgical and transcatheter closure group.

In agreement with our findings, other studies as **Balcı et al.** [12] **and Chen et al.**[13] had found significant increase in the LV ejection fraction in ASD patients post closure.

In contrast to our study, **Teo et al.** [18], **Mangiafico et al.** [19] **and Vijayvergiya et al.**[20] have found there was no significant change in LVEF in ASD patients post closure, although both LVEDV and LVESV increased.

Tricuspid annular plane excursion, which is easy to record, reflects RV function along the long axis, reflects the systolic RV function and has also been shown to be closely related to the RV ejection fraction. [13]

In the current study, we observed that TAPSE was significantly reduced after ASD closure either surgical orpercutaneuse. This can be explained by the closure of left to right shunt, hence the less volume overload of the RV, or probably a true reduction in RVEF. [13]

In keeping with our findings, **Lange et al.** [11] **and Islamlı et al.**[22] reported that TAPSE decreased significantly after ASD closure indicating reverse RV remodeling**, Chen et al.**[13] demonstrated that (TAPSE) reduced significantly after surgery, which may be due to the less volume overload of the RV.

In contrast to our results, **Balcı et al.** [12] demonstrated that TAPSE remained unchanged. They attributed that to the anatomical complexity of the right ventricle, difference in orientation of myocardial fibers, and reduced wall thickness may play a role in this result.

In the current study, right ventricular MPI indices by pulsed wave tissue Doppler showed that, there was a significant decrease in the RVMPI after ASD closure as compared to before closure.

This is in agreement with other publications as **Chen et al.**[13] **and Yılmazer et al.**[24] who reported similar findings for RVMPI.

In explanation of the above findings; the fact that the right ventricular remodeling started after closure of ASD, these were mainly due to left to right shunt is blocked, right heart volume and pressure load rapidly decreased, and the right cardiac systolic& diastolic functions improved partly. This phenomenon might also been related to myocardial compliance of the right ventricle. [13]

In contrast to our findings, **Islamlı et al.** [22] detected that, there was significant increase in RVMPI after ASD closure. **Ding et al.** [23] also reported that the increase in right ventricular Tei index was primarily due to prolongation of right ventricular IVRT in a wide age range of the patient population.

On the other hand, **Monfredi et al.** [25] failed to show any significant change in either RV or LV MPI values. One reason for the controversy in former results in evaluating RV performance may be the limitation of two-dimensional echocardiography in evaluating the RV due to its unsuitable geometry.

In our study, the RVMPI showed significant decrease after both surgical& device closure with no statistical difference between both groups. **Eidem et al.**[26] observed that the MPI index measured post-surgical did not show significant changes after ASD closure and has indicated that this may be contributed to cardiopulmonary bypass which is avoided by percutaneous closure.

In the current study, left ventricular MPI indices by pulsed wave tissue Doppler showed no significant changes after ASDclosure in both surgical and device groups, with no significant difference between both groups. This is in agreement with **Yılmazer et al.**[24] **and Monfredi et al.**[25]

On the other hand, **Wu et al.** [21] have reported that device closure of ASD was associated with significant improvement in the left ventricular Tei index in the adult population**.** They have attributed this improvement to the restoration of LV compression and the increase in left ventricular filling.

The echocardiographic study and quantitative evaluation of right ventricular (RV) functions are still challenging due to the RV complex anatomy and structure. Therefore, several studies have documented insufficient reliability and accuracy of assessment of RV volume and ejection fraction by traditional 2D and M-mode classic evaluation. [16]

Using 3-.D echocardiography can overcome several important limitations of 2-D echocardiography by neglecting geometric assumptions and using multiple images to reconstruct the RV chamber. [28]

In our study, the RV evaluation by 3- D echocardiography shored that, there was a significant decrease in 3- D RV end-diastolic volume, 3- D RV end-systolic volume and 3- D RV EF in the ASD patients after ASD closure in both device and surgical groups.

This is may be contributed to; larger heart volume increases the initial length of the muscle fiber, which enhances cardiac contractility and stroke volume based on the Frank-Starling law. The high values returned to normal after ASD closure and abolishment of the left to- right shunt. [17]

In keeping with our findings, **Balcı et al.**[12] **and Vitarelli et al.**[16] also showed a significant decrease in RV end-diastolic volume and RV end-systolic volume post-closure.

Eerola et al. [29] demonstrated decreases in diastolic RV dimensions, along with significant increases in LV diastolic and systolic dimensions by 3- D echocardiography.

In a report by **Ding et al.** [30]; they showed a significant decrease in RV end-diastolic volume and RV end-systolic volume post-closure, resulting in a marked decrease of the RV ejection fraction.

Regarding to LV evaluation by 3- D, in our study there was no significant changes in LV end diastolic volume, LV end systolic volume& LV EF after ASD closure in either post device group or post surgical group. In agreement with our findings, **Tashiro et al.** [31] have similar findings.

RV diastolic function should be included in the routine evaluation of the RV as it is a marker of early or subtle global RV dysfunction; also, it often precedes systolic dysfunction. Evaluation of the RV diastolic function is mainly based on tricuspid valve inflow using PWD and on tricuspid annulus motion using DTI. [32]

Tissue Doppler Imaging (TDI) is commonly used as a new echocardiographic technique that uses a modification of the conventional color Doppler technology in which measures signals arising from the tissue, rather than from blood flow. The use of pulsed tissue Doppler allows mitral and tricuspid annular motion to be studied and has enhanced the noninvasive examination of right and left ventricular systolic and diastolic function. [30]

In our study, the trans-tricuspid diastolic inflow velocities by conventional pulsed wave Doppler in ASD patient underwent catheter closure showed a significant decrease in the early diastolic tricuspid E wave velocity in ASD patients following percutaneous closure. The late diastolic tricuspid A wave velocity showed no significant decrease in ASD patients post device closure. **Cheung et al.** [27] have demonstrated a significant decrease in trans-tricuspid diastolic pulse wave velocities E and A waves following percutaneuse closure of ASD.

In our study, the tricuspid E /A ratio in ASD patients underwent transcathetere closure, showed a significant decrease after ASD device closure. In keeping with our results, **Akula et al.** [36] had shown a significant decrease in E/A ratio after device closure.

In our study, concerning to trans-mitral diastolic inflow velocities by conventional pulsed wave Doppler in ASD patient underwent ASD transcatheter closure; we did not find significant changes in E wave, A wave, E/A ratio or deceleration time in ASD patients as comparing pre versus post device closure.

In agreement with our study, **Tashiro et al.** [31] had reported no significant change in E, A, E/A ratio. In contrast to our study, **Yılmazer et al.** [24] had demonstrated a significant increase mitral E wave & E/ A ratio. These findings were explained by; this may be due to reduced preload resulting from shunting through the ASD at baseline, but probably not to the diastolic dysfunction of the left ventricle.

In our study, the trans-tricuspid diastolic inflow velocities by conventional pulsed wave Doppler in ASD patient underwent ASD surgical closure showed a significant decrease in the early diastolic tricuspid E wave and late diastolic tricuspid A wave velocities in ASD patients following surgical closure.

In keeping with our findings, **Vijayvergiya et al.** [(20)] have demonstrated a significant decrease in trans-tricuspid diastolic pulse wave velocities following surgical repair of ASD. They suggested this decrease in velocities to their dependence on RV preload, which decreases following ASD repair.

Concerning to, the tricuspid E/A ratio in ASD patients underwent surgical closure; there were no significant changes after ASD closure.

In keeping with our results, **Vijayvergiya et al.**[(20)] **and Akyüz et al.**[(37)] showed insignificant change in tricuspid E/A ratio; suggesting a relatively preserved filling pressure and RV diastolic function following surgery.

In our series, concerning to trans-mitral diastolic inflow velocities by conventional pulsed wave Doppler in ASD patient underwent ASD surgical closure; there were no significant changes in E wave, A wave, E/A ratio or deceleration time in ASD patients after surgical closure.

In accordance with our study, **Vijayvergiya et al.** [(20)] found no significant difference in trans-mitral pulse Doppler velocities and E/A ratio before versus after surgical closure of ASD. They established this insignificant change in mitral E/A ratio, is suggestive of unchanged LV diastolic function following surgery.

In our study, regarding to the assessment of RV diastolic function by transtricuspid pulsed wave TDI in ASD patients under went catheter closure, the trans- tricuspid E' wave and A' wave TDI annular velocities showed no significant difference in ASD patients post device closure.

In contrast to the result, **Ammar et al.** [(38)] concluded that tissue transtricuspid TDI diastolic annular velocities decreased significantly after ASD device closure.

Agha et al.[(33)] suggested that to an acute volume unloading of the right side of the heart and redirection of the pulmonary venous returns toward the LV.

In our study, the tricuspid E/E' ratio n ASD patients under went catheter closure showed significant decrease in ASD patients after device closure. In accordance to our findings, **(Akula et al.** [(36)] showed significant decrease in tricuspid E/E' ratio in ASD patients after device closure. In contrast to the result of ricusid E/E', **Mangiafico et al.** [(19)] revealed no significant changes after ASD device closure.

The peak annular or basal systolic velocities are strong predictors of outcome in several conditions. [(34)] The peak systolic velocity is also a sensitive marker of mildly impaired LV systolic function, even in those with a normal LVEF or apparently preserved LV systolic function, such as “diastolic heart failure”, or in diabetic subjects without overt heart disease. [(35)]

In our study, the systolic (S') tricuspid TDI annular velocity in ASD patients under went catheter closure showed no significant difference in ASD patients after device closure.

In contrast to our study, other studies as **(Akula et al.** [(36)] **and Ammar et al.** [(38)] reported that RV systolic velocity, tricuspid (S’) decreased significantly after ASD catheter closure.

Akula et al.[(36)] had explained that the increased preload in right ventricle had high basal RV systolic function following Starling’s law of the heart. Because the S' is, load dependent parameter, so significant decrease post-ASD device closure creating a doubt of RV systolic dysfunction, but are normal according to the ASE guidelines. This may explain the observation of high normal baseline RV systolic function in ASD patients, which normalizes after device closure.

In our study, regarding to the assessment of LV diastolic function by transmitral pulsed wave TDI in ASD patients under went catheter closure, the trans- mitral both medial and lateral E' wave and A' wave TDI annular velocities showed no significant difference in ASD patients post device closure.

In keeping with our findings, **Tashiro et al.** [31] showed no significant changes in trans-mitral TDI annular velocities following ASD device closure.

In contrast to our study, **Agha et al.**[33] had demonstrated significant decrease in trans-mitral tissue Doppler velocities following ASD device closure.

In our study, the mitral E/E' ratio n ASD patients underwent catheter closure showed significant increase in ASD patients after device closure.

In agreement with our study, **Yılmazer et al.** [24] had similar findings, he reported that the ratio of E/ E' mitral velocity was significantly increased during the follow-up in ASD patients after trancatheter closure. In contrast to our study**, Mangiafico et al.** [19] demonstrated significant decreased mitral E/E' ratio in patients of ASD before and after ASD closure.

In our study, the systolic (S') mitral TDI annular velocity in ASD patients under went catheter closure showed no significant difference in ASD patients after device closure. In contrast to our study, **Agha et al.**[33] had demonstrated sigficant decrease in (S') mitral in ASD patients after device closure.

In our study, regarding to the assessment of RV diastolic function by transtricuspid pulsed wave TDI in ASD patients under went surgical closure, the trans- tricuspid E' wave and A' wave TDI annular velocities showed significant decrease in ASD patients post surgical closure. In keeping with our findings, **Vijayvergiya et al.** [20] had demonstrated that tissue Doppler-derived tricuspid diastolic annular velocities decreased significantly after ASD device closure.

In our study, the tricuspid E/E' ratio showed significant decrease in ASD patients after surgical closure. In contrast to the result of tricuspid E/E', **Vijayvergiya et al.**[20] revealed no significant changes after ASD surgical closure.

In our study, the systolic (S') tricuspid TDI annular velocity in ASD patients under went surgical closure showed significant decrease in ASD patients after surgical closure. In keeping with our findings, **Vijayvergiya et al.**[20] had demonstrated significant decrease in tricuspid S' wave after ASD surgical closure.

In our study, regarding to the assessment of LV diastolic function by transmitral pulsed wave TDI in ASD patients under went surgical closure, the trans- mitral lateral E' wave and A' wave TDI annular velocities showed no significant difference, while the medial wave and A' wave TDI annular velocities showed significant decrease in ASD patients post surgical closure.

Vijayvergiya et al. [20] had detected insignificant decrease in the mitral E`wave TDI (medial& lateral) annuli post ASD surgical closure, this was in keeping with our study regarding E` wave lateral mitral annulus but in contrast to regarding the medial mitral annulus. While, they showed a significant decrease in A' wave TDI (medial& lateral) annuli in ASD patients after surgical closure, this was in keeping with our study regarding A' wave medial mitral annulus but in contrast to regarding the lateral mitral annulus.

In our study, the mitral E/E' ratio n ASD patients underwent surgical closure showed no significant difference in ASD patients after surgical closure. In keeping with our findings, **Vijayvergiya et al.**[20] had detected no significant difference in the E/E' ratio in patients of ASD after ASD surgical closure, suggesting unchanged filling pressure and LV diastolic function following surgery.

In our study, the systolic (S') mitral TDI annular velocity in ASD patients under went surgical closure showed no significant difference at the lateral mitral S' while, showed significant decrease at the medial mitral S' in ASD patients after surgical closure. In keeping with our findings for the lateral mitral S', **Vijayvergiya et al.** [20] had demonstrated no significant decrease in mitral S' wave after ASD surgical closure.

In our study, regarding to comparing the RV and LV diastolic functions in ASD patients after closure in transcatheter group versus surgical group, there were no significant difference in transtricuspid or transmitral diastolic conventional Doppler inflow velocities or the tissue Doppler annular velocities except for, the E/E' ratio was increased significantly in post device closure than surgical closure.

Myocardial deformation imaging techniques have developed recently as a new non-invasive method for quantitative assessment of myocardial wall motion by measuring strain, S (ϵ) and strain rate (SR). [(39)]

Myocardial strain and strain rate are more accurate than velocities as indices of ventricular contractility. Strain rate values appeared to be dependent on pressure overload but less dependent on volume overload compared to strain. [(16)]

In our study, we found that; the RV anterior wall (free wall) basolateral (apical) and basal strain decreased significantly post ASD closure in both catheter and surgical groups.

As regarding the longitudinal septal strain; the basal, mid and apical septal strain were decreased significantly after ASD closure in both catheter and surgical groups. As an explanation to our findings, **Vitarelli et al.** [(16)] reported that, in patients with chronic RV volume overload due to an ASD, the RV longitudinal strain in ASD patients decreased significantly after closure. They had explained their findings to that; larger heart volume increases the initial length of the muscle fibers, which enhances cardiac contractility and stroke volume based on the Frank-Starling law. The high values returned to normal after ASD closure and abolishment of the left to- right shunt.

In keeping with our findings, regarding to the longitudinal right ventricular strain, **Bussadori et al.** [(40)] had demonstrated that the longitudinal right ventricular strain showed significant reduction in all segments of the lateral wall and of the right septum after ASD closure.

In agreement with our findings concerning to the RV apical segment strain, **Van De Bruaene et al.**[(41)] demonstrated significant increased apical strain in patients with an open ASD and significant decreased apical strain values in patients with a closed ASD, especially in those who underwent surgical closure.

In our study, the RV longitudinal strain of the basal segment were significant higher in ASD patients pre-closure than those in post- closure. **Ko et al.** [(39)] attributed the lower post-closure values may be due to the remodeling of RV basal free wall, and the higher pre-closure values may be due to compensation caused by the increased preload.

In keeping with our findings, concerning to the apical segment, **Ko et al.**[(39)] reported increased deformation of the RV apical segment in pre-closure ASD than those in post-closure.

In contrast to our findings, **Eyskens et al.**[(42)] reported that the relief of chronic RV volume overload by ASD closure was associated with a non significant decrease of end-systolic strain and peak systolic SR.

In our study, the longitudinal strain of LV lateral wall apical (basolateral) and basal strain showed no significant increase after ASD closure either catheter or surgical closure

In our study, the strain rate of all segments showed no significant difference between ASD patients' pre closure as compared to post in both surgical and percutaneuse groups.

CONCLUSION

From the present study, we conclude that; a significant shunt in the secundum ASD affects right and left ventricular sizes, systolic and diastolic functions. Three-dimensional (3D) echocardiography, tissue Doppler imaging (TDI) and deformation imaging are promising tools in estimating RV dysfunction in those cases. Patients who underwent either transcatheter device closure or surgical repair, showed almost comparable rates of improvement of RV and LV systolic and diastolic functions and sizes within the first few months.

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