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Alteration of Pulmonary Venous Flow Doppler Post Transcatheter Closure of Atrial Septal Defect

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Atrial septal defect is a common congenital heart anomaly results in hemodynamically significant right ventriclular volume overload and an increase in the pulmonary venous flow.

Aim: Evaluate changes of pulmonary venous flow parameters after transcatheter closure of secundum atrial septal defect.

Patients and Methods: 50 patients with atrial septal defect aged from 3.5 to 31 years were included in the study. Pulmonary venous flow Doppler and right ventricular function were evaluated before and after successful transcatheter closure by transthoracic and transesophageal echocardiography.

Results: The defect size ranged from 15 to 37mm with a mean (24.96 ±7.52), Normal systolic and diastolic waves of pulmonary venous flow Doppler were replaced by a continuous antegrade wave (mean 60±13.6 cm/s) in all atrial septal defect patients. Post-closure, the normal pulmonary venous flow pattern was regained, two separate waves, with a significant decrease in mean peak Systolic wave velocity (44.54±8.12 cm/sec vs 69.61±12.37, P=0.000), the mean peak Diastolic Wave velocity (55.85±9.81 cm/sec vs 72.65±10.38, P=0.000) and a significant increase in the mean peak atrial reversal wave velocity (28.75±4.63cm/sec vs 21.18±3.64, P=0.000). In multivariate regression analysis, significant predictors of haemodynamic significant ASD were ASD size,(odds ratio 1.508, P=0.007, 95% CI 1.153,2.671) and ASD/IAS ratio (odds ratio 2.313, P=0.001, 95% CI 1.064,3.104).

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Conclusions: Atrial septal defect patients have characteristic pulmonary venous flow pattern: continuous antegrade wave with systolic predominance and decrease in atrial reversal wave, which return to normal after closure. These changes could be helpful echocardiographic tool in prediction of successful closure of the defect.

Keywords: Atrial Septal Defect Secundum Type (ASDII); Pulmonary Venous Flow (PVF); Pulmonary Artery Pressure (PAP).

1. INTRODUCTION

Atrial septal defect is a common congenital heart disease. It is safely closed surgically or by transcatheter approach. Indications for intervention include large left-to-right shunt or paradoxical embolization [1].

Transthoracic echocardiography is the gold standard tool for diagnosis and follow-up of ASD. However, transesophageal echocardiography provide more accurate and better imaging quality [2,3].

PVF Doppler is composed of the S wave recorded during (ventricular systole), the D wave during(ventricular diastole),and the AR wave at(atrial systole) [4]. ASD causes reversal of the PVF pattern. However, it is not known exactly to how extent closure of the shunt can affect PVF patterns in different age groups [5].

2. PATIENTS AND METHODS

This prospective observational study included 50 patients (23 children and 27 adult patients) aged from (3.5 to 31 years) who have secundum type of ASD, without severe pulmonary hypertension or any other cardiac defects. All patients were subjected to complete history taking & full clinical examination, 12 leads electrocardiogram, full 2D TTE and TEE. They all underwent successful percutaneous transcatheter ASD closure guided by TTE and TEE between October 2018 and March 2021 at Tanta University Hospitals, Cardiology Department.

Evaluation of the PVF Doppler, PAP and RV function were done before and compared with the changes that occurred after (within 48 hours) post-ASD transcatheter closure by using TTE and TEE.

Assessment of the following parameters by TTE: ASD location, size, shape, number, its relation to other cardiac structures especially pulmonary veins and the presence of right-sided heart dilatation). Regarding ASD, it can be examined through subcostal 4 chamber view which is the best view, subcostal sagittal view, apical 4 chamber view and parasternal short-axis view. In the apical 4-chamber view, the pulmonary veins were identified. the pulse wave (PW) Doppler of 2 mm width was positioned within the right and left pulmonary veins. The PVF Doppler pattern was then obtained and was repeated post-closure to compare PVF patterns (Figs. 1 and 2). RV systolic function assessment was done by tricuspid annular plane excursion (TAPSE) and Right ventricular end-diastolic diameter (RVEDD) [6-8]. TEE was done for better imaging quality and a more accurate assessment of device suitability and size selection. ASD can be examined through upper esophageal short-axis view, mid esophageal 4 chamber view, mid esophageal aortic view, mid esophageal bicaval view and mid esophageal long-axis view [9,10]. Identification of pulmonary venous flow Doppler was done by the 4 main mid esophageal views including left atrial appendage view, modified bicaval view, modified left upper pulmonary vein (LUPV) view, modified right upper pulmonary vein (RUPV) view [10,11].

2.1 Statistical Analysis

All data were collected, tabulated and statistically analyzed using SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA).

Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi-square test ($\chi 2$) and Fisher exact were used to calculate the difference between qualitative variables as indicated. Quantitative data were expressed as mean ± SD (Standard deviation) and range. Independent T-test and Mann Whitney test were used to calculate the difference between quantitative variables in two groups for parametric and non-parametric variables respectively. Multiple logistic regression models were constructed for comparisons, odd ratio (OR) and 95% confidence intervals (CI) were provided to establish which variables are predictors of

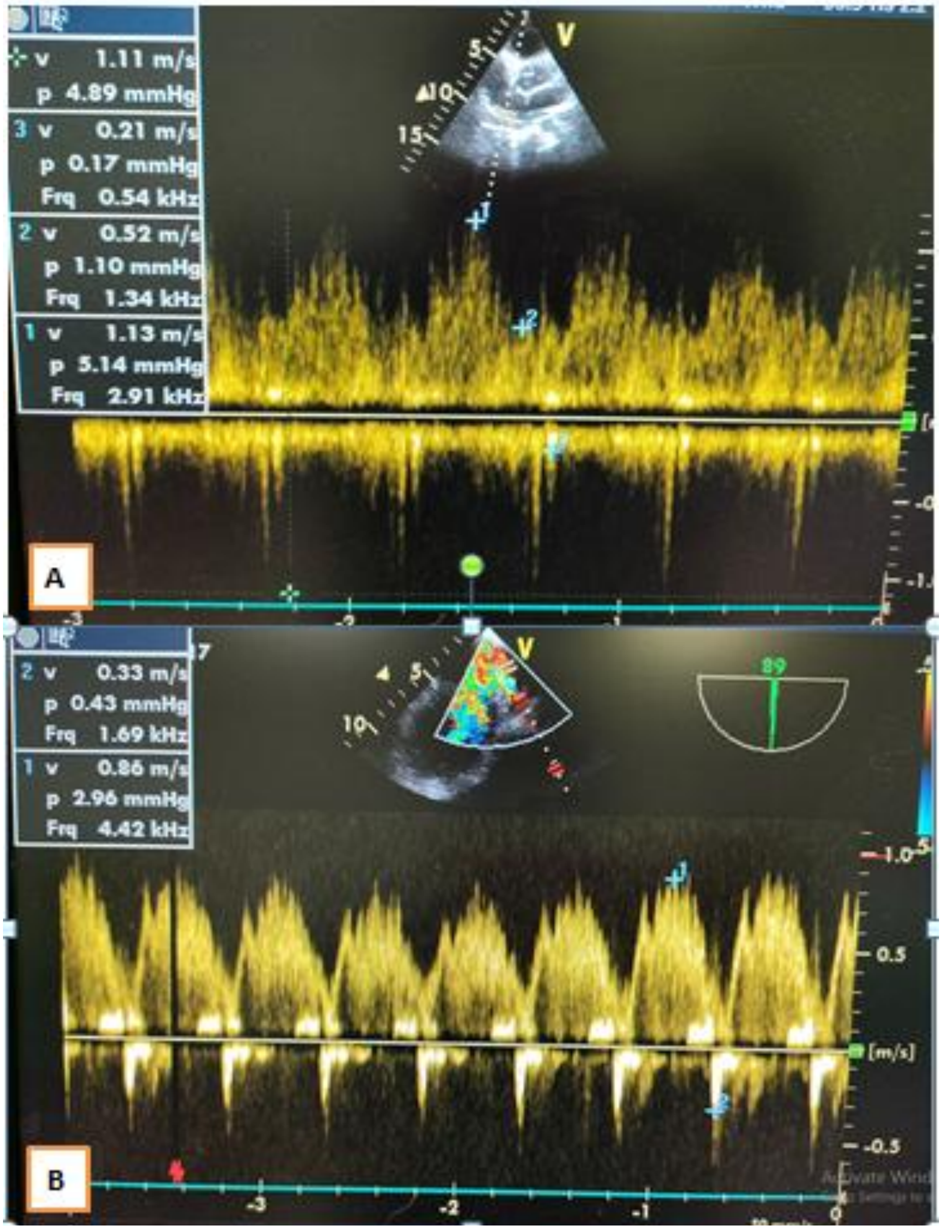

Fig. 1. Pulmonary venous flow pattern by transthoracic (A) and transesophageal (B) echocardiography of female patient aged 27 years old (70 kg) before ASDII closure showed continuous single antegrade wave with diminished AR wave

hemodynamically significant ASD. All statistical comparisons were two-tailed with a significance level of P-value ≤ 0.05 indicates significance, p <0.001 indicates highly significant difference while P> 0.05 indicates Non-significant difference.

3. RESULTS

This prospective observational study included 50 patients aged from (3.5 to 31 years), who underwent successful percutaneous trans-catheter closure of ASD guided by TTE and TEE between October 2018 and March 2021, In Tanta University Hospital, Cardiology Department. Patients were followed up post ASD closure.

Transthoracic and Transesophageal echocardiographic measurements of peak Diastolic and systolic flow velocities, the ratio of peak S/D flow velocities, and the peak AR velocity of the RUPV correspond well with each other. In this study, TTE has a 92% (36 out of 40) success rate in PVF Doppler assessment.

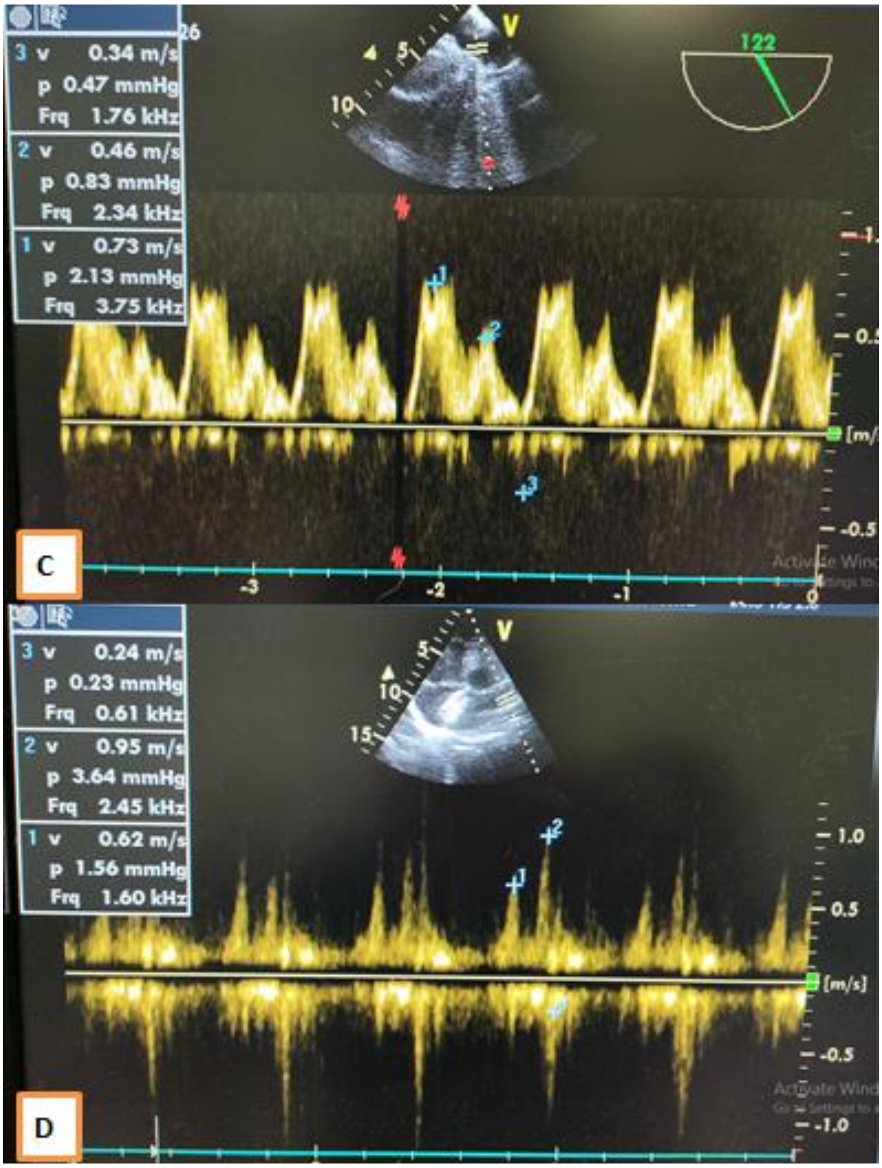

Fig. 2. Pulmonary venous flow Doppler by trans-esophageal (C) and transthoracic (D) echocardiography of the same patient after successful closure of ASDII, showed immediate splitting of the antegrade wave after closure and increase in AR wave (C) with further improvement 3 months post procedure (D)

3.1 Demographic Data and Clinical Presentation

The age of the included patients ranged from 3.5 years to 31 years, with a mean of 18.26 ± 2.46 and a median of 19.5 years old. There were 34 females (68%). The mean body mass index ranges from (21.12 ± 1.08) and the median of 22.8. The body surface area mean ranges from (1.47± 0.11) according to DU Bois formula, and median of 1.72. In the current study, 6 children were asymptomatic (12%), 6 patients (12%) presented with recurrent chest infections, 38 patients (76%) presented with exercise intolerance, dyspnea and fatigue.

3.2 Echocardiographic Parameters

The size of ASD ranged from 15-37 mm with a mean of 24.96 ± 7.52. Most cases (45 patients, 90%) showed normal PAP before and after closure (Tables 1, 2). Only few cases (10%) showed a mild to moderate increase in PAP before closure. The mean PAP of studied patients was 34.62 ± 8.27 (Table 2).

3.3 Pulmonary Venous Flow Pattern Distribution

The PVF pattern in ASD patients before closure showed characteristic fused S and D waves (a continuous antegrade wave) with a mean (60 ±• 13.6 cm/s), there was a systolic predominance, (S > D) in both the RUPV (38 patients, 76%) and the LUPV (42 patients, 84%). Moreover, there were no significant difference changes between measurements through right and left upper pulmonary veins (RTUPV and LTUPV) (Fig. 1)

Post ASD closure, the continuous antegrade wave was replaced by distnict systolic and diastolic Waves. Morover,There was a significant decrease in S-wave (69.61 ± 12.37 cm/sec pre-closure vs 44.54 ± 8.12 cm/sec, P=0.000), D-Wave (72.65 ± 10.38 cm/sec vs 55.85 ± 9.81 cm/sec , P=0.000) and a significant increase in AR wave (21.18 ± 3.64 cm/sec pre-closure vs 28.75 ± 4.63 cm/sec post-closure, P=0.000). Heart rate showed a slight non-significant decrease after closure. (P=0.242) (Table 2), (Fig. 2).

3.4 Right Ventricular Function

There was no significant difference between RV function by TAPSE (25.84 ± 3.95 pre-closure vs 23.90 ± 2.50 post-closure, P=0.07) and RVEDD (35.22 ± 6.57 pre-closure vs 33.82 ±5.2 post-closure, P=0.12) (Table 2).

3.5 The Possible Predictors of Hemodynamically Significant ASD

In the multivariate regression analysis, ASD size and ASD/IAS ratio were found to be significant predictors of the presence of hemodynamically significant ASD (Table 3).

4. DISCUSSION

ASD is the most common acyanotic congenital heart disease (approximately accounts for 40% of adult cardiac shunts). Patients with a volume overload of the right heart chambers, without evidence of irreversible pulmonary hypertension, indicate that closure of the shunt is required to prevent ventricular dysfunction, lung congestion, recurrent chest infection, arrhythmias and other symptoms of heart failure [12].

Transcatheter closure of ostium secundum ASD is an excellent alternative to surgery provided that the defect is amenable for device closure according to the defect size and presence of adequate rims around the defect [13].

Table 1. Transthoracic echocardiography findings in the studied patients

Parameters	**Patients** (n=50)
ASD size (m^2) Mean ± SD	24.96 ± 7.52
IAS length (mm) Mean ± SD	45.27 ± 3.41
ASD/IAS ratio Mean ± SD	0.492 ± 0.426
Continuous antegrade wave (cm/sec)	60 ± 13.6
RVEDD (mm) Mean ± SD	35.22 ± 6.57

Data were presented as Mean ± SD.
Abbreviation: ASD: Atrial Septal Defect,
IAS: Interatrial Septum,
RVEDD: Right Ventricular End-Diastolic Diameter

Table 2. Echocardiographic parameters of the studied patients

Echocardiographic parameters	**Pre-closure**	**Post-closure**	**P-value**
Systolic wave velocity (S) (cm/sec)	69.61 ± 12.37	44.54 ± 8.12	0.000*
Diastolic wave velocity (D) (cm/sec)	72.65 ± 10.38	55.85 ± 9.81	0.000*
Atrial reversal (AR) wave velocity (cm/sec)	21.18 ± 3.64	28.75 ± 4.63	0.000*
TAPSE (cm) Mean ± SD	25.84 ± 3.95	23.90 ± 2.50	0.07
RVEDD (mm) Mean ± SD	35.22 ± 6.57	33.82 ±5.2	0.12
PAP (mmHg) Mean ± SD	34.62 ± 8.27	30.52 ±5.6	0.10

*Data were presented as Mean ±SD. *denotes significant change.*
Abbreviation: TAPSE: Tricuspid Annular Plane Systolic Excursion, PAP: Pulmonary Artery Systolic Pressure

Table 3. Regression analysis to detect the possible predictors of the presence of hemodynamically significant IAS

	OR	S.E.	Sig.	95% C.I. for OR	
				Lower	Upper
ASD size	1.508	.071	.007*	1.153	2.671
ASD/IAS ratio	2.313	.058	.001*	1.064	3.104
RVEDD	1.264	.047	.063	.978	1.846
PAP	2.084	.032	.056	1.715	4.611

*Data were presented as odd's ration and 95% confidence interval. * denotes significant changes.*
Abbreviation:ASD: Atrial Septal Defect, IAS: Interatrial Septum,
RVEDD: Right Ventricular End-Diastolic Diameter, PAP: Pulmonary Artery Pressure

This prospective study included 50 patients, whose age ranged from 3.5 to 31 years with mean 18.26 ± 2.46 and median 19.5 years. They had hemodynamically significant ASD referred for evaluation of suitability of percutaneous device closure in the cardiology department at Tanta University Hospitals in the period from October 2018 to March 2021.

All patients in this study were eligible for ASD closure, they had hemodynamically significant left to right shunt based on echocardiography in the form of dilated right side structures regardless of clinical symptoms related to ASD.

In this study, there was female predominance, as they represent 68% of patients, most of them over 20 years old around the childbearing period. This study is to clarify the characteristic pattern of PVF Doppler in ASD patients who have hemodynamically significant left to right shunt, the study showed that it was formed of Continuous single antegrade wave, increased systolic wave velocity more than diastolic wave velocity with ratio S/D >1 in measurement, and the Pulmonary vein atrial reversal (retrograde flow) is decreased.

These changes returned to be normal after successful transcatheter closure of ASD. A possible explanation for this might be that pulmonary veins have no valves and are in direct communication with the left atrium (LA), so pulmonary venous flow is affected by both physiological factors as heart rate or age and also pressure gradient among pulmonary veins and left atrium (PV-LA gradient). In normal conditions, the maximum LA filling occurs during ventricular systole (Systolic forward movement) and early LV diastole (Diastolic forward movement), and atrial reversal wave occurs during atrial contraction [14].

In ASD patients, the continuous shunting of blood to the right atrium, and the independece from LV contraction, are believed to result in the observed prominent continuous antegrade waveform. Accelerated LA emptying through the ASD continuous shunt leads to decreased LA building-up pressure that leads to decreased atrial reversal wave or even being absent. After ASD closure, all PVF parameters return gradually to normal [3,15].

Transthoracic echocardiography is ideal for congenital heart disease defects screaning as it is a noninvasive, widely available diagnostic tool. Lam YY et al. studied the relation between PVF Doppler and the presence of significant secundum ASD before closure and 1 day after closure. 50 patients were included (14 males & 36 females), age of the studied patients ranged from (36 ± 17 years). In agreement with our study, they concluded that pre-closure S and D antegrade wave velocity increased and atrial reversal wave decreased in ASD patients. These findings return to normal after closure [16].

In agreement with the current study, Chockalingam A et al. studied the role of transthoracic PVF in ASD patients. The study included 44 patients with mean age 21.4 ± 8.7 years, ASD size ranged from 10-38mm with a mean 18 ± 4.2 mm, they concluded that normally S and D waves in transthoracic echo are replaced by continuous antegrade wave and atrial reversal wave diminished or even absent [17].

Lin WW et al. were in agreement with this study they studied changes of trans-esophageal pulmonary venous flow immediately after ASD closure by occluder device on 48 patients with different age groups below 16ys and above 16ys. They found that S and D waves decreased and atrial reversal wave increased after closure [18].

Saric et al. were in agreement with our study, as they found no difference in measuring the pulmonary venous flow Doppler velocity in left versus right or superior versus inferior pulmonary veins [2].

In agreement with our study, Parsaee et al. found that right ventricular systolic function changes are considered statistically non-significant [5].

RV function can't be easily assessed by transthoracic echo because mathematical equations are unable to measure its variable shape as it has variable sizing as a compensatory effect of volume changes. It can be measured by M mode on the lateral plane of the tricuspid annulus (TAPSE) [19,20,21].

5. CONCLUSION

The presence of hemodynamically significant ASDII in young adults results in a characteristic continuous antegrade wave with systolic predominance and diminished or absent atrial reversal wave. These changes reversed after shunt closure. Thus, PVF Doppler can be used as an additional non-invasive, available tool in follow-up of ASD patients.

CONSENT AND ETHICAL APPROVAL

The study was approved by the Ethical Committee, Quality Assurance Unit, Faculty of medicine, Tanta University on Human Research, Code no: 33366/09/19 and date: 09/2019. Informed consent was obtained from the patients or one of their parents before percutaneous transcatheter closure of ASD.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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