The Relation between Left Atrial Appendage Contraction Velocity and Continues Antegrade Wave of PVF in Patients with ASD

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Abstract

Introduction: Large uncomplicated atrial septal defect (ASD) alters the pulmonary venous flow (PVF) pattern. The left atrial appendage (LAA) flow characteristics in ostium secundum (ASD) have not been previously studied in detail.

Objective: We aimed to study the alteration in PVF flow pattern in relation with LAA in patients with large uncomplicated ASD.

Patients & Methods: The correlation between LAA flow pattern and PVF pattern were assessed in (29) subjects, with ASD. The mean age of the study group was (36 ± 12.142) years. All subjects in sinus rhythm, which were examined with transthoracic (TTE) and transesophageal echocardiography (TEE).

Results: LAA flow pattern and PVF pattern were adequately recorded in 29 subjects with ASD. Maximum diameter (1.4cm) to (3.90 cm). The mean age of the study group was (mean ± SD: 36 ± 12.142) years. All patients with sinus rhythm. Continuous antegrade wave (CAW) of PVF pattern (mean ±SD:52.52 ±10.683 cm/sec) replaced normally occurring S and D wave in all ASD patients. The atrial reversal wave was reduced (mean ± SD: 23.629 ± 6.29 cm/sec). There is strong correlation between peak LAA contraction velocity and peak CAW velocity of PVF (r = -0.5269 P< 0.001).

Conclusions: Transesophageal Doppler echocardiography of LAA flow and PVF patterns in patients with ASD can help to estimate ASD hemodynamics. And may add as a new diagnostic way for the defect.

Key words: Transesophageal echocardiography, Left atrial appendage flow, Doppler, Atrial Septal Defect, Pulmonary Venous Flow

Introduction

There are many different types of Atrial Septal Defect (ASD), depending upon in the interauricular septum. They are most often found in the area of fossa Ovalis and referred to as a secundum ASD.[1]

Transesophageal echocardiography (TEE) is the excellent imaging tool in the diagnosis and evaluation of ASD. [2], since the advent of TEE, PVF and LAA patterns can be assessed easily and clearly.[3,4]. In normal individuals with sinus rhythm, pulmonary venous flow patterns consist of a biphasic or triphasic forward flow waves and an atrial reversal.[5, 6]. Specific flow patterns, reflecting appendage function, have been characterized for normal sinus rhythm and various abnormal cardiac rhythms.[7]. Normal LAA Doppler flow pattern in a large population have been reported recently.[8], in sinus rhythm, consist of LAA contraction wave, LAA filling (an early systolic negative Doppler in flow signal), systolic reflection waves, (a variable number of alternating LAA outflow and inflow signals of diminishing amplitude are commonly recorded) following LAA contraction and filling.[9, 10], and early diastolic LAA flow.[11, 12] Large uncomplicated ASD alters the PVF pattern.[13, 14, 15] And pulmonary vein velocities have not been used in conjunction with left atrial appendage (LAA) flow velocities to increase our understanding of ASD.

The purpose of this study was systematically comparing the changes in pulmonary venous and left atrial appendage flow velocities during ASD.

Methods & Patients:

We evaluated PVF and LAA flow in 29 patients (26 females, 3 males) with large uncomplicated secundum ASD. There were all adults, whose age ranged from (16) to (56) years; (mean ± SD: 36 ± 12.142) years.

Study participant underwent clinical evaluation, TEE, and TTE. The current analysis of LAA function and PVF was performed in 29 subjects fulfilling the following criteria:

Sinus rhythm during the echocardiographic examination. 1- There were no clinical or echocardiographic signs of significant valvular or myocardial abnormalities increased pulmonary resistance or right–to–left shunting.

For obvious ethical and practical reasons, we could not perform TEE healthy volunteers or, patients with normal heart. We made comparison with historical controls.

LAA flow categorized into one of the three patterns: biphasic, triphasic and quadraphasic. Quadraphasic signals have been described in patients with sinus rhythm. Fig. (1) [7, 8]. It was consist of LAA contraction, LAA filling, systolic reflection wave (positive and negative), and early diastolic LAA outflow. The normal values for LAA flow were depicted in table (1).[16]

The normal PVF usually shows a tri or quadraphasic pattern consisting of a pulmonary venous early systolic wave (S1), pulmonary venous late systolic wave (S2), pulmonary venous early diastolic wave (D), and pulmonary venous atrial reversed flow wave (AR).[17,18] (Fig.2), table (2).
Fig. (1) Pulsed Doppler tracing of LAA flow in sinus rhythm (flow signals 1 to 4). 1, LAA contraction; 2, LAA filling; 3, systolic reflection waves (positive and negative); 4, early diastolic LAA outflow.

Table (1) LAA Contraction and Filling Velocities in subjects without Cardiac Disease.

<table>
<thead>
<tr>
<th>Velocities (cm/s) by Age Group (yrs)</th>
<th>45 – 54 (n = 78)</th>
<th>55 – 64 (n = 90)</th>
<th>65 - 74 (n = 65)</th>
<th>75 - 84 (n = 48)</th>
<th>≥85 (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Contraction velocities</strong></td>
<td>80 ± 23</td>
<td>77 ± 23</td>
<td>71 ± 27</td>
<td>69 ± 20</td>
<td>63 ± 29</td>
</tr>
<tr>
<td><strong>Filling velocities</strong></td>
<td>61 ± 18</td>
<td>57 ± 17</td>
<td>54 ± 18</td>
<td>53 ± 13</td>
<td>54 ± 17</td>
</tr>
</tbody>
</table>

From Agmon. Y et al. [16]

Fig. (2) Pulmonary venous flow velocity profile in normal subject. Pulmonary venous systolic wave is usually greater than diastolic wave.

Note the pulmonary venous systolic wave (S). AR: pulmonary venous atrial reversal wave; D: pulmonary venous diastolic wave.
Table (2): Normal pulmonary venous flow velocity.

<table>
<thead>
<tr>
<th>Peak S (cm/s) TEE</th>
<th>10-19 yrs</th>
<th>20-29 yrs</th>
<th>30-39 yrs</th>
<th>40-49 yrs</th>
<th>50-59</th>
<th>&gt;60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35±14</td>
<td>49±13</td>
<td>54±17</td>
<td>58 ± 15</td>
<td>70±14</td>
<td>64±19</td>
</tr>
<tr>
<td>Peak D (cm/s) TEE</td>
<td>81±16</td>
<td>61±10</td>
<td>53±17</td>
<td>53±10</td>
<td>48±11</td>
<td>44±13</td>
</tr>
<tr>
<td>Peak AR (cm/s) TEE</td>
<td>18±5</td>
<td>23±8</td>
<td>20±8</td>
<td>24±9</td>
<td>23±10</td>
<td>25±6</td>
</tr>
<tr>
<td>S: D TEE</td>
<td>0.43±0.23</td>
<td>0.81±0.19</td>
<td>1.08±0.28</td>
<td>1.13±0.4</td>
<td>1.51±0.35</td>
<td>1.57±0.57</td>
</tr>
</tbody>
</table>

Table from: S.F.de Marchi et al.\textsuperscript{[10]}

S: peak systolic flow velocity.
D: peak antegrad diastolic flow velocity.
S: D, ratio of systolic to diastolic peak flow velocity.

Echocardiography:
All patients were studied using Philips medical ultrasonogramograph. (Philips Envisor, ultrasound system).

Two – dimensional and Doppler TEE were performed after the (TTE) study with a (2.5 – 3.5) MHZ transducer.
A 5 – MHZ Multiplane probe was used to perform TEE in the left lateral decubitus position. All subjects fasted for >4h before the TEE study. Intravenous sedative with diazepam (2.5 to 5 mg) and topical pharyngeal anesthesia with lidocaine (Xylocaine) spray were administrated before insertion of the esophageal probe.

LAA was viewed from the midesophageal position in the transverse and longitudinal biplane as well as intermediate Multiplane views\textsuperscript{[4]} and LAA flow was interrogated by pulsed – wave Doppler (2 - to 5 mm sample volume was placed with the proximal third of the appendage, adequately located within the LAA cavity to avoid wall motion artifacts. Filter and gain settings were adjusted to obtain optimal LAA flow recordings\textsuperscript{[19]}. From which LAA contraction and filling velocity were measured.

PVF velocity profiles were obtained by pulsed wave Doppler echocardiography with the sample volume placed in the upper pulmonary vein, approximately 0.5 – to 1 cm proximal to the entrance into the left atrium.

Measurement obtained from Doppler echocardiography tracing included the peak velocity of flow waves and the velocity - time integral VTI for both systolic and diastolic flows.

The diagnosis of ASD was established by two dimensional echocardiography and confirmed by color flow mapping and pulsed Doppler spectral analysis at the level of the atrial septum.

Statistical analysis:
Statistical analysis was performed using SPSS ver 12 (statistical package for social sciences). In association with Excel version 2003.

Pearson correlation coefficient was used to study the direction and strength of association between continuous variables. Statistical significance was taken as $P< 0.05$.

Data in the tables are presented as the mean value ± standard deviation.

Results
The maximal ASD diameter ranged from (1.4) cm to (3.90) cm (Mean ± SD: 2.3662 ± 0.78540). The direction of the shunt was from the left atrium to the right atrium in all patients. All patients were in normal sinus rhythm.

Pulmonary venous flow velocity pattern:
The pattern consisted of a single antegrade wave (lasting from the onset of ventricular systole to the onset of atrial contraction) and a retrograde wave (after atrial contraction), the amplitude which was smaller than those in historical controls. The antegrade flow velocity component in our 29 patients with ASD lacked the distinct systolic and diastolic waves that are observed in healthy persons (Fig 3); we refer to this component as the continuous antegrade wave (CAW). The peak of CAW velocity among all study patients ranged between (67.8 - 122.0) cm/sec. (Mean ± SD: 89.9207 ± 14.795 cm/sec).

Table (3) shows pulmonary venous flow velocities in (29) patients with ASD.

Although all study patients were in normal sinus rhythm, the usual reversal of flow from the left atrium into the pulmonary veins with atrial contraction (AR wave) was small. The peak AR velocity ranged between (18.3-29.3) cm/sec, (Mean ± SD: 23.63 ± 3.1195).
Fig. (3) Pulsed Doppler recording of pulmonary venous flow velocity pattern in patient with ASD.

Table (3) Pulmonary venous flow velocities in (29) patients with ASD.

<table>
<thead>
<tr>
<th>Parameter of PVF pattern</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VTI cm</td>
</tr>
<tr>
<td>CAW Cm/sec</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>19.30 - 49.70</td>
</tr>
<tr>
<td></td>
<td>Means ± SD</td>
</tr>
<tr>
<td></td>
<td>30.3534 ± 8.8</td>
</tr>
<tr>
<td>AR Cm/sec</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>0.7 – 3.34</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>2.10 ± 0.810</td>
</tr>
</tbody>
</table>

CAW: continuous antegrade wave of PVF (cm/sec)
AR: Atrial contraction wave of PVF (cm/sec)
PVF: pulmonary venous flow.
LAA flow velocity pattern:
The pattern consists of table (4) Fig (4):
*LAA contraction velocity in a late diastolic positive (i.e., toward the transducer) Doppler outflow signal, the peak LAA contraction velocity ranged between (15.7 – 50) cm/sec. (Mean ± SD: 30.0132 ± 11.245).

*LAA filling velocity: negative (away from the TEE transducer) Doppler inflow signal. The peak LAA filling velocity ranged between (24.70 – 68.90) cm/sec. (Mean ± SD: 41.3679 ± 13.473) cm/sec.

Table (4) TEE assessment of the study population.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>VTI (cm)</th>
<th>V (max) (cm/sec)</th>
<th>V mean (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAA contraction velocity (cm/sec)</td>
<td>Range</td>
<td>25.7 - 96.3</td>
<td>15.70 – 50.0</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>4.5232 ± 1.855</td>
<td>30.0132 ± 11.245</td>
</tr>
<tr>
<td>LAA filling velocity (cm/sec)</td>
<td>Range</td>
<td>24.7 – 68.9</td>
<td>1.51 – 38.3</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>3.5218 ± 1.7517</td>
<td>21.2761 ± 8.8473</td>
</tr>
<tr>
<td>Continuous wave PVF (cm/sec)</td>
<td>Range</td>
<td>67.8 – 122.0</td>
<td>37.5 – 69.3</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>30.35±8.76342</td>
<td>52.5172±10.684</td>
</tr>
<tr>
<td>Atrial reversal PVF (cm/sec)</td>
<td>Range</td>
<td>18.3 – 29.3</td>
<td>16.3 – 9.8</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>2.1045 ± 0.810</td>
<td>13.438± 2.108</td>
</tr>
</tbody>
</table>

VTI: Velocity time integral. (cm)
V (max): maximum velocity (cm/sec)
V (mean): mean velocity (cm/sec)

Fig. (4) Pulsed Doppler recording of the left atrial appendage flow in subject with ASD and in sinus rhythm.
LAA flow velocity pattern and PVF pattern:
Strong correlation were observed between maximum LAA contraction velocity (Vcmax) of LAA flow velocity pattern and maximum velocity of continues antegrade wave (CAW) of PVF (r = -0.526. p < 0.001). Fig. (5), Table (5).

![Graph showing correlation between LAA contraction velocity and PVF pattern](image)

Fig. (5) Correlation of continuous antegrade wave velocity (cm/sec) with LAA contraction velocity cm/sec in patients with ASD.

### Table (5) Correlation of LAA flow Doppler Echocardiographic variables with continuous antegrade wave (CAW) of PVF.

<table>
<thead>
<tr>
<th>Variables</th>
<th>R</th>
<th>P – value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak LAA contraction velocity (cm/sec)</td>
<td>-0.526</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Peak LAA filling (cm./sec)</td>
<td>-0.0337</td>
<td>0.079 (N.S)</td>
</tr>
</tbody>
</table>

(N.S): Not Significant

**Discussion**
Since there is little information regarding the role of LAA flow in ASD patients, our study demonstrated that the relationship between LAA flow and PVF using TEE in patients with sinus rhythm.

As a result, a peculiar pattern of PVF. In current study we observed that PVF, as recorded by TEE has continuous antegrade wave (CAW) and a diminished AR wave in all cases. Fig. (3) These description coinciding with previous studies \[^{13, 14, 15}\], which described the same results.

Normally, left atrial pressure varies with ventricular filling and contraction \[^{5, 6}\], pulmonary venous drainage into the left atrium is biphasic, with more PVF during ventricular contraction (S) and during early diastolic filling period (D). As pulmonary veins do not have valves, blood refluxes back during atrial contraction (atrial reversal wave, AR) \[^{20}\].
The peculiar PVF Doppler pattern in patients with significant ASD, initially proposed by Sari et al. [14]. He suggested that in patients with ASD, the entire pulmonary venous return dose not cross the mitral valve (as in the case in health persons), but rather is divided between the flow across the mitral valve and the flow across the ASD. Unlike healthy persons in whom the left atrium becomes a dead-end chamber during ventricular systole, patients with ASD have a left atrium that is in constant communication with the complaint, low resistance right side of the heart throughout the cardiac cycle. This persistent egress of blood from the left atrium via the ASD throughout the cardiac cycle allows for a continuous flow into the left atrium from the pulmonary veins.

Saris et al. [14] hypothesized that this continuous inflow into the left atrium leads to the loss of distinct S and D waves and their replacement with CAW.

Discrete Doppler flow signals have been described by Agmony et al. [15, 16] in a large population of normal subjects. The normal Doppler flow signals of LAA consist of four waves, Fig. (1).

The essential LAA wave, is LAA contraction, resulting in a late diastolic, positive (i.e., toward the TEE transducer) Doppler outflow signal, shortly flowing the onset of the ECG, P-wave. This signal coincides with two-dimensional and color flow imaging of LAA contraction and outflow [19], and is related temporally to late diastolic mitral flow (mitral A-wave) [20], its measurement has been demonstrated to be reproducible and correlated with LAA ejection fraction [16].

The second component is LAA filling, an early systolic, negative (i.e., away from the TEE transducer) Doppler inflow signal, immediately following left atrial contraction [19].

There is little information regarding the relation of left atrial appendage function to PVF pattern in human.

In recent experimental studies, it has been shown that removal of the LAA decreases left atrial compliance and increases left atrial pressure at any given volume and that LAA plays important role in left atrium reservoir function [22, 23].

Tukek T. et al. [24] demonstrated the pathological changes of LAA and investigated the correlation between LAA function and PVF pattern. He concludes that LAA is a contractile structure, and that systolic PVF velocity is influenced by LAA dysfunction.

Therefore LAA function needs to be considered when interpreting Doppler transmirtal and systolic PVF patterns. In light of these findings the significant correlation between the peak of LAA contraction wave and peak continuous antegrad wave of PVF, \( r = -0.526, \ P < 0.001 \) table (4) Fig. (4) in our study confirms that this strong correlation sheds new light on the hemodynamics of LAA function and ASD.

This results might have some clinical implications in addition; pulmonary venous flow variables used in conjunction with LAA flow velocities are an attractive means of evaluating hemodynamics of ASD noninvasively.

This description of both PVF and LAA flow patterns in ASD patients will allow better understanding of the effects of pathologic conditions on PVF, and LAA flow and possibly provide further insight into the mechanism of atrial and ventricular systolic and diastolic function.

Limitations of the study:
We have not studied the changes in the ASD. PVF pattern in the presence of pulmonary hypertension. Invasive estimation of ASD size or shunt quantification is not part of the protocol. We did not evaluate restrictive ASD or patent foramen ovale where the PVF may not show this CAW pattern seen in our series. Continuous antegrade flow occurs in pulmonary vein stenosis and PVF may also be altered in conditions like pulmonary valvular stenosis. We have studied PVF patterns only among subjects with confirmed ASD.

Conclusion
Transeosophageal echocardiography can provide valuable and reliable information about the LAA flow velocities and PVF velocities in ASD patients with sinus rhythm. Atrial septal defect, when associated with significant left - to - right shunting, alters the PVF pattern. This alteration associated strongly with LAA contraction velocity. LAA flow and PVF Doppler in ASD offers an additional Doppler echocardiographic tool in the screening, confirmation and hemodynamics evaluation of atrial septal defects, and the understanding the function of LAA in ASD patients.

References

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