Transthoracic Doppler Echocardiographic Measurement of Left Atrial Appendage Blood Flow Velocity: Comparison with Transoesophageal Measurement

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Aim: We validated transthoracic echocardiographic measurements of left atrial appendage flow velocity by comparing them with transoesophageal echocardiographic measurements.

Methods and Results: Eighty-four consecutive patients (mean age, 64.6 years) with various cardiac diseases, who underwent both transthoracic echocardiography and transoesophageal echocardiography were studied. Thirty-two patients were in sinus rhythm, and the remaining 52 patients were in atrial fibrillation. On transthoracic echocardiography, the transducer was placed somewhat superior and outside from the position viewing the conventional parasternal short-axis image of the aortic valve, so that the angle between left atrial appendage midline and Doppler beam could be narrowed. The left atrial appendage flow velocity pattern was recorded by pulsed Doppler mode with a sampling volume placed at the left atrial appendage orifice on both transthoracic echocardiography and transoesophageal echocardiography. In both approaches, the peak emptying velocity (LAA-E) and the peak filling velocity (LAA-F) of the left atrial appendage were measured. In sinus rhythm, the LAA-E was detectable in 25 of the 32 patients (78.1%) and the LAA-F in 20 of the 32 patients (62.5%). Both LAA-E and LAA-F were detectable in 46 of the 52 patients (88.5%) in atrial fibrillation. Good correlations of LAA-E and LAA-F were observed between transthoracic echocardiography and transoesophageal echocardiography measurements in sinus rhythm ($r = 0.94$, $r = 0.95$, respectively; both, $P < 0.0001$) and in atrial fibrillation ($r = 0.89$, $r = 0.95$, respectively; both, $P < 0.0001$).

Conclusions: The left atrial appendage flow velocities could be sufficiently recorded and assessed by transthoracic echocardiography in 84 Japanese unselected consecutive patients with sinus rhythm or atrial fibrillation.

Key Words: left atrial appendage flow velocity; transthoracic echocardiography; transoesophageal echocardiography.

Introduction

Measurement of the left atrial appendage flow velocity is considered to be useful for evaluating left atrial function or blood flow stasis in the left atrium[1-4]. Left atrial appendage flow velocity has generally been recorded by the semi-invasive method of transoesophageal echocardiography. Recent advancement in echocardiography, i.e. tissue harmonic imaging, enables us to visualize left atrial appendage structure more clearly than fundamental imaging[5-7] and to measure left atrial appendage flow velocity to some extent by transthoracic echocardiography[7,8]. However, it is still sufficiently unknown that what are the visualization rate of the left atrial appendage and the detection rate of the left atrial appendage flow velocity by transthoracic echocardiography, and whether transthoracic echocardiography measurements of left atrial appendage flow velocity provide reliable quantifications. This study was an attempt to validate transthoracic echocardiography measurements of left atrial appendage flow velocity.

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by comparing them with transoesophageal echocardiography measurements.

### Methods

#### Patients

We studied 84 consecutive Japanese patients with various cardiac diseases, who underwent transthoracic echocardiography and transoesophageal echocardiography at the Division of Cardiology in our hospital. These patients (50 men, 34 women) were aged between 41 and 83 years (mean 64.6 years). Thirty-two patients were in sinus rhythm, and the remaining 52 patients were in atrial fibrillation. Underlying diseases of the 32 patients with sinus rhythm were paroxysmal atrial fibrillation in eight, mitral stenosis in seven, mitral regurgitation in six, dilated cardiomyopathy in five, hypertension in four, and aortic stenosis and atrial septal defect in one, and those of the 52 patients with atrial fibrillation were isolated atrial fibrillation in 24, mitral stenosis in eight, mitral regurgitation in seven, mitral valve replacement in five, hypertrophic cardiomyopathy in four, and prior myocardial infarction and hypertension in two. Body mass index of the patients ranged from 18.5 to 35.7 (mean 24.0). All patients gave informed consent, and the protocol was approved by the review board of our hospital.

#### Transthoracic and Transoesophageal Echocardiography

Transthoracic echocardiography was performed with patients in the left lateral decubitus position with a SSD-2200 echocardiographic imaging system (Aloka, Tokyo, Japan). A 2.5 MHz monoplane transducer was used. The transducer was placed somewhat superior and outside from the position viewing conventional parasternal short-axis image of the aortic valve, so that the angle between left atrial appendage midline and Doppler beam could be narrowed. The left atrial appendage was carefully sought and visualized on the left side of the aorta and on the right inferior side of the main pulmonary trunk. Image quality of the left atrial appendage was categorized into three classes: good, sufficient, and poor quality. The left atrial appendage flow velocity patterns were characterized by an emptying (LAA-E) wave immediately after the electrocardiographic (ECG) P wave, followed by a filling (LAA-F) wave. The LAA-E waves were detectable in 25 of the 32 patients (78.1%) and the LAA-F waves in 20 of the 32 patients (62.5%). On the left atrial appendage orifice on a transverse section (Fig. 1, left upper).

#### Velocity Measurements and Data Analysis

In both approaches, the peak emptying velocity (LAA-E) and the peak filling velocity (LAA-F) of the left atrial appendage were measured. Transoesophageal and transthoracic Doppler parameters were obtained by two investigators without the knowledge of each other’s results and patients’ characteristics. The averaged values of five cardiac cycles were used for analysis.

#### Statistics

Values are expressed as mean ± standard deviation. Statistical analysis utilized StatView 4.5. Relationships between two variables were tested by a simple linear regression analysis using least-squares method. A level of $P < 0.05$ was accepted as statistically significant.

#### Results

##### Visualization of the Left Atrial Appendage by Transthoracic Echocardiography

Image quality of the left atrial appendage was good in 39 of the 84 patients (46.4%), sufficient in 35 of the 84 patients (41.7%), and poor in 10 of the 84 patients (11.9%).

##### Detection of the Left Atrial Appendage Flow Velocity by Transthoracic Echocardiography

The left atrial appendage flow velocity was detectable by transthoracic echocardiography in 66 of the 84 patients (78.6%), and of these patients, left atrial appendage images were of good quality in 39 (59%) and of sufficient quality in 27 (40.9%). In the patients who were in sinus rhythm, left atrial appendage flow velocity patterns were characterized by an emptying (LAA-E) wave immediately after the electrocardiographic (ECG) P wave, followed by a filling (LAA-F) wave (Fig. 1, middle lower). The LAA-E waves were detectable in 25 of the 32 patients (78.1%) and the LAA-F waves in 20 of the 32 patients (62.5%).
the other hand, left atrial appendage flow velocity was undetectable during systolic to early diastolic phase in most atrial fibrillation patients, although clear multiple irregular waves were noted during mid- to late diastolic phase (Fig. 1, right lower). Both LAA-E and LAA-F waves were detectable in 46 of the 52 patients (88.5%) in atrial fibrillation. The detection rate was higher in atrial fibrillation than in sinus rhythm.

**Intra-observer and Inter-observer Variabilities**

Intra- and inter-observer mean percentage errors for LAA-E velocity obtained by transthoracic echocardiography were 2.0 $\pm$ 2.9 and 4.6 $\pm$ 2.6%, respectively. Intra- and inter-observer mean percentage errors for LAA-F velocity obtained by transthoracic echocardiography were 3.0 $\pm$ 2.6 and 4.8 $\pm$ 3.5%, respectively.

**Comparison Between Transthoracic and Transoesophageal Approaches**

The angle between ultrasonic beam and left atrial appendage midline ranged from 21$^\circ$ to 30$^\circ$ (mean 25.7$^\circ$) in transthoracic echocardiography, and ranged from 3$^\circ$ to 10$^\circ$ (mean 6.3$^\circ$) in transoesophageal echocardiography. In all the patients, both LAA-E and LAA-F velocities showed good positive correlations between transthoracic echocardiography and transoesophageal echocardiography measurements ($r = 0.92$, $r = 0.96$, respectively; both, $P < 0.0001$), although the values obtained from transthoracic echocardiography were smaller than those from transoesophageal echocardiography (Fig. 2). These correlations of LAA-E and LAA-F velocities were also shown between transthoracic echocardiography and transoesophageal echocardiography measurements in sinus rhythm ($r = 0.94$, $r = 0.95$, respectively; both, $P < 0.0001$) and in atrial fibrillation ($r = 0.89$, $r = 0.95$, respectively; both, $P < 0.0001$).

In 26 patients with atrial fibrillation who had LAA-E or F velocity less than 25 cm/s in transthoracic echocardiography, 20 patients showed LAA-E or F velocity less than 25 cm/s in transoesophageal echocardiography. Thus, positive predictive value was 76.9%. In contrast, in 26 patients with atrial fibrillation whose LAA-E or F velocity was 25 cm/s or more in transthoracic echocardiography, only one patient showed LAA-E or F velocity less than 25 cm/s in transoesophageal echocardiography. Thus, negative predictive value was 96.2% (Table 1).

**Discussion**

Transoesophageal echocardiography is commonly used for the assessment of the left atrial blood stasis and left atrial appendage thrombi$^{9-12}$. However, this technique is a 'semi-invasive' examination accompanied by various complications in about 3% of the cases$^{13}$. 

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Figure 1. Methods of determining left atrial appendage flow velocities by transoesophageal (upper) and transthoracic (lower) echocardiography. Flow velocity recordings were obtained from a patient with sinus rhythm (middle) and with atrial fibrillation (right). Ao, aorta; LA, left atrium; LAA-E, peak emptying left atrial appendage flow velocity; LAA-F, peak filling left atrial appendage flow velocity; PA, pulmonary artery.
The left atrial appendage has been only suboptimally visualized by conventional transthoracic echocardiography. Advancement of echocardiography enables us to visualize left atrial appendage structure by transthoracic echocardiography [5–7]. Recently, there have been some reports trying to measure left atrial appendage flow velocity using tissue harmonic imaging by transthoracic echocardiography [7,8]. However, they are still insufficient about the visualization rate of the left atrial appendage and the detection rate and/or reliability of the measurements of left atrial appendage flow velocity by transthoracic echocardiography. In this study, we tried to place the transducer superior and outside from the position viewing the short-axis image of the aortic valve to visualize the left atrial appendage cavity and to make the angle between left atrial appendage midline and Doppler beam narrow. Consequently, we were able to visualize the left atrial appendage with a good or sufficient image quality in 88% of the subjects and to measure the left atrial appendage flow velocity in 68.8% of patients with sinus rhythm and in 84.6% of patients with atrial fibrillation by transthoracic echocardiography. Moreover, the left atrial appendage flow velocity showed a good correlation between

Figure 2. Correlations between transoesophageal and transthoracic measurements of the peak emptying (left) and filling (right) left atrial appendage flow velocities in patients with sinus rhythm (SR) and atrial fibrillation (AF). TEE, transoesophageal echocardiography; TTE, transthoracic echocardiography. Other abbreviations are as in Fig. 1.
Transthoracic LAA Flow Velocity Measurement

From these results, we conclude that the left atrial appendage flow velocities could have been accurately recorded and assessed by transthoracic echocardiography in 84 Japanese unselected consecutive patients with sinus rhythm or atrial fibrillation.

**References**


**Study Limitations**

Conclusion

In this study, the angle between ultrasonic beam and left atrial appendage midline ranged from 21° to 30° in transthoracic echocardiography, so no angle correction was performed in measuring left atrial appendage flow velocity. If the angle between both lines exceeds 30°, angle correction will be necessary, but obtained velocity may be unreliable. Another limitation is that how do we understand if we can obtain a low left atrial appendage flow velocity. It is difficult to find out whether the value is correct or underestimated. Other findings, such as left atrial or left atrial appendage size, wall motion of the left atrial appendage, and so on, should also be considered. If the possibility of a low left atrial appendage velocity is high, transesophageal echocardiography should be performed.

In this study, in 26 patients with atrial fibrillation whose LAA-E or F velocity was 25 cm/s or more in transthoracic echocardiography measurements. The value obtained from transthoracic echocardiography was slightly smaller than that from transesophageal echocardiography. This can be explained by the following two reasons: the angle between left atrial appendage midline and Doppler beam was greater in transthoracic echocardiography than in transesophageal echocardiography (Fig. 1, left), and the peak left atrial appendage flow velocity during early diastole was not measurable in atrial fibrillation due to contamination signals from the pulmonary artery. However, this result can be beneficial from the following viewpoint. The left atrial appendage flow velocity obtained from transesophageal echocardiography may not be smaller than that from transthoracic echocardiography. In this study, in 26 patients with atrial fibrillation whose LAA-E or F velocity was 25 cm/s or more in transthoracic echocardiography, only one patient showed LAA-E or F velocity less than 25 cm/s in transesophageal echocardiography. Therefore, if the higher left atrial appendage flow velocity can be obtained by transthoracic echocardiography in some patient with atrial fibrillation, it is speculated that blood stasis or thrombus formation may hardly occur in the left atrial appendage of that patient. Further investigations in a large number of patients should be performed to confirm this speculation.

**Table 1.** Number of cases categorized by left atrial appendage emptying (LAA-E) or filling (LAA-F) flow velocity in transthoracic and transesophageal approaches in 26 patients with atrial fibrillation.

<table>
<thead>
<tr>
<th>TTE-LAA-E or F</th>
<th>≥25 cm/s</th>
<th>&lt;25 cm/s</th>
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<tbody>
<tr>
<td>&lt;25 cm/s</td>
<td>6</td>
<td>20</td>
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<tr>
<td>≥25 cm/s</td>
<td>25</td>
<td>1</td>
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TEE, transoesophageal echocardiography; TTE, transthoracic echocardiography.