Estimation of Left Atrial Pump Function by Mitral Annular Velocity

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Background: Estimation of left atrial (LA) pump function is important for the management of cardiac patients. The purpose of this study is to elucidate the role of mitral annular late diastolic velocity (A') determined by transthoracic echocardiography as a parameter to predict LA pump function.

Methods and Results: One hundred and four consecutive patients that were scheduled for paroxysmal atrial fibrillation (AF) ablation, in whom both multi-detector computed tomography (MDCT) and echocardiography during sinus rhythm prior to ablation were performed, were enrolled in this study. To determine the echocardiographic parameters that most accurately represent LA pump function, the relationship between LA emptying fraction (LAEF) obtained by MDCT and echocardiographic parameters including A' were examined. A' was the only echocardiographic parameter that was significantly correlated with LAEF (r=0.59, P<0.0001). Receiver-operating characteristic curve analysis showed that when impaired LA booster pump performance was defined as an LAEF <30%, an A' cutoff value of 7.4 cm/s had a sensitivity of 93%, specificity of 81%, predictive accuracy of 83%, positive predictive value of 43% and a negative predictive value of 99%.

Conclusions: A' is a simple, non-invasive and reliable method to estimate LA pump function in patients with paroxysmal AF. (Circ J 2012; 76: 1430–1435)

Key Words: Atrial fibrillation; Atrium; Computed tomography; Echocardiography; Tissue Doppler imaging

The left atrium functions as a passive reservoir storing blood from the pulmonary veins during ventricular systole and as a conduit for sending blood from the pulmonary veins to the left ventricle during ventricular diastole. In addition, the left atrium acts as an active booster pump ejecting blood into the left ventricle during late ventricular diastole. Among these functions, left atrial (LA) booster pump function might be more important because cardiac performance relies more on LA booster pump function in patients with left ventricular dysfunction than in healthy subjects.1,2 Recently available multi-detector computed tomography (CT) and magnetic resonance imaging have been shown to be very reliable for the measurement of LA volumetric parameters.3–5 However, these imaging examinations cannot be easily and repeatedly performed in routine clinical practice because of their prohibitive costs and the exposure of patients to radiation, strong magnetic fields and contrast media. Echocardiography is a widely available and non-invasive modality that has been used to measure LA volume, but echocardiographic measurements of LA volume using Simpson’s rule or the area-length method, and measurements of LA contractility using the strain method, are often time-consuming and require skilled operators.6,7 Mitral annular late diastolic velocity (A’) is easily measured with tissue Doppler imaging and could be a robust marker of LA function. To establish a simple and reliable method of accessing LA function, we investigated the relationship between echocardiographic parameters including A’ and LA emptying fraction (LAEF) obtained by CT in patients with paroxysmal atrial fibrillation (AF).

Methods

Patient Population
From April 2008 to March 2010, we enrolled consecutive patients that underwent both CT and echocardiography and who were also scheduled for catheter ablation of paroxysmal AF. Exclusion criteria were as follows: absence of sinus rhythm during CT and/or echocardiography, prior AF ablation, prior cardiac surgery, moderate to severe aortic and mitral valve diseases according to the guidelines,8 coronary artery disease, left ventricular systolic dysfunction (left ventricular ejection fraction <50%), atrial fibrillation, atrial flutter, or other cardiac arrhythmia, or other cardiac disease that might affect cardiac performance.
fraction <50%), and inadequate echocardiographic or CT images. Antiarrhythmic drugs were discontinued 5 half-lives before CT and echocardiography. Written informed consent for CT and clinical trial enrollment was obtained from all patients. This study was approved by our institutional review board.

CT
CT was performed within 1 week before AF ablation with a 64-row CT scanner (Brilliance CT 64; Phillips Medical Systems, Amsterdam, Netherlands). A beta-blocker was not used prior to scanning. The scan technique was defined by the attending physician in charge. The slice collimation was 64×0.625 mm. A bolus of non-ionic iodinated contrast (Iopamiron 370; Bayer, Leverkusen, Germany) was injected through an antecubital left ventricular at a rate of 0.67 ml·min⁻¹·kg⁻¹ for 15 s, followed by a saline bolus chaser. The scan was started with a delay of 6 s after the threshold of 120 Hounsfield Units was reached in the descending aorta. Cardiac images from the carina to the apex of the heart were acquired during 1 breath-hold. All data were processed using an Extended Brilliance Workspace (Phillips Medical Systems).

The entire RR interval was divided into 20 phases. In each phase, the left atrium was divided into 9 slices along its long axis, originating from the most superior point of the roof and perpendicular to the plane of the mitral annulus. The LA endocardial border, excluding pulmonary veins and the LA appendage, was manually traced to obtain an area measurement for each slice. By integrating the area measured in each slice along the LA long axis, the LA volume was obtained in each phase of the cardiac cycle. LAEF was calculated as follows: LAEF=(maximum LA volume−minimum LA volume)/maximum LA volume×100. We divided the study patients into 2 groups based on the median LA volume index: Group 1 consisted of patients with slight LA remodeling defined as an LA volume index ≤the median; and Group 2 consisted of patients with advanced LA remodeling defined as an LA volume index >the median. Furthermore, we defined impaired LA booster pump function as LAEF <30% using LAEF in the healthy subjects (mean−2SD) according to a previous report.³

Echocardiography
Transesophageal echocardiography was performed on the day before AF ablation using a Sonus iE33 (Philips, Andover, MA, USA). The LA diameter was measured between the LA posterior and anterior walls at the mitral annulus in the parasternal long-axis view. Left ventricular ejection fraction was assessed with Simpson’s method using the apical 2- and 4-chamber views. Peak velocities of early (E) and late (A) diastolic transmitral Doppler flow were measured using the apical 4-chamber view with the sample volume placed at the tip of the mitral leaflets. Mitral annular velocities during early (E’) and late (A’) diastole were measured by tissue Doppler imaging with the sample volume placed at the basal septum using the apical 4-chamber view. Emptying velocity was measured by placing the pulsed Doppler sample volume at the outlet of the appendage cavity more than 1 cm away from the LA cavity.

Statistical Analysis
All values are expressed as the mean±SD unless otherwise indicated. A Student’s t-test was used to compare continuous variables, and a chi-square or Fisher’s exact test was used to compare categorical variables between the 2 groups of patients. To assess correlations between the continuous variables, Pearson’s correlation coefficient analysis was performed. For the prediction of impaired LA function, a receiver-operating characteristic curve was constructed for A’. The area-under-the-curve was determined along with the 95% confidence interval using the bootstrap method. All analyses were conducted using SPSS for Windows, version 15.0.

Results
We enrolled 165 patients that underwent CT and echocardiography and were scheduled for ablation for paroxysmal AF as described in the inclusion criteria. The major reasons for exclusion were: a history of prior AF ablation (36 patients), the presence of organic heart disease (34 patients), the absence of sinus rhythm at the time of CT and/or echocardiography (18 patients) and inadequate echocardiographic images (3 patients). Thus, the final study population consisted of 104 patients. We divided the study patients into 2 groups based on the median value of the LA volume index: Group 1 (n=52) consisted of patients with slight LA remodeling (LA volume index ≤44.2 cm³/m²) and Group 2 (n=52) consisted of those with advanced LA remodeling (LA volume index >44.2 cm³/m²).
As shown in Table 1, there were no differences in the baseline clinical factors between Group 1 and Group 2, except for a higher frequency of hypertension in Group 2. A majority of patients were prescribed with type I antiarrhythmic drugs according to the clinical guidelines in Japan. Upon CT examination, LAEF was significantly lower in Group 2 than in Group 1 (Table 2). More patients in Group 2 tended to have left ventricular hypertrophy than those in Group 1. Additionally, patients in Group 2 had lower E’ and higher E/E’ on echocardiography than those in Group 1. There were 8 patients that have elevated left ventricular end-diastolic pressure (E/E’ >15), and all of them had concomitant hypertension and hypertrophy, suggesting hypertensive heart disease. In contrast, other transthoracic and transesophageal echocardiographic parameters including left ventricular ejection fraction, E/A, A’, and LA appendage emptying peak velocity were similar between the 2 groups.

**Association Between CT and Echocardiography**

We also evaluated the associations between the echocardiographic parameters and LAEF measured by CT (Table 3). Among the echocardiographic parameters, only A’ demonstrated a modest correlation with LAEF in patients in both Group 1 and 2 (Figure 2). Furthermore, the significant correlation between A’ and LAEF was also observed in patients both with and without left ventricular hypertrophy (r=0.66, P=0.0001 and r=0.59, P<0.0001). In contrast, patients with an E/E’ >15 did not demonstrate a significant correlation between A’ and LAEF (r=0.43, P=0.30), although in patients with an E/E’ ≤15, A’ and LAEF correlated (r=0.62, P<0.0001).

Of 104 study patients, 14 patients had impaired LA pump function defined as a LAEF <30%. Therefore, receiver-operating characteristic curve analyses were performed using echocardiographic parameters. As shown in Figure 3, A’ was the best echocardiographic parameter with an area-under-the-curve of 0.92. The best cutoff value for A’ was 7.4 cm/s with a sensitivity of 93%, specificity of 81%, predictive accuracy of 83%, positive predictive value of 43% and a negative predictive value of 99%.
In the present study, we evaluated paroxysmal AF patients scheduled for AF ablation to determine the most useful transthoracic echocardiographic parameter to estimate LA pump function. This study population included quite a few patients with left ventricular hypertrophy, which was probably due to hypertension, and some of them had impaired left ventricular diastolic dysfunction. The main results were: A’ was significantly correlated with LAEF obtained by CT; and an A’ value of 7.4 cm/s was the best cutoff value for the prediction of impaired LA pump function.

Among the echocardiographic parameters, only A’ demonstrated a significant correlation with LAEF. Because A’ is a direct measurement of intrinsic atrial longitudinal myocardial velocity, this parameter should be least affected by intra and extra atrial hemodynamic factors, and this might account for its correlation with LAEF. In contrast, other parameters like transmitral Doppler flow and LA appendage emptying flow are indirect measurements of blood flow derived from LA contraction. Furthermore, we demonstrated a moderate correlation between A’ and LAEF not only in patients with slight LA remodeling (Group 1) but also in those with advanced LA remodeling (Group 2). Furthermore, this correlation was also observed in patients both with and without left ventricular hypertrophy. These results are important for the clinical ap-
application of A’ because patients with a wide severity of LA remodeling and a left ventricular diastolic dysfunction are encountered in routine clinical practice.

In contrast, the correlation between A’ and LAEF was not demonstrated in patients with elevated E/E’ (n=8), In addition, another possible explanation is that A’ was affected by elevated left ventricular end-diastolic pressure, and this negated the correlation between the 2 parameters. This explanation is supported by a study reporting that A’ is determined not only by LA dp/dt but also by left ventricular end-diastolic pressure in dogs.12

Previously, several studies investigated the relationship between A’ and atrial pump function.13 Khankirawatana et al reported the usefulness of A’ to estimate LA function because they found a correlation between A’ and LAEF obtained by echocardiography.14 The correlation between A’ and LA fractional area and volume change was also demonstrated using echocardiography in a study by Hesse et al.15 The advantage of our study is that we obtained LAEF by CT, which is more reliable for the measurement of LA volumetric parameters.16 Furthermore, our study subjects had paroxysmal AF, and this is similar to the population that frequently requires the measurement of LA function.

The mean value of A’ in this study was 8.4±2.2 cm/s, and this is lower than that in age-matched healthy subjects.17 Depressed atrial contractility due to atrial remodeling in our study patients would explain this discrepancy. Additionally, in some patients, atrial stunning just after conversion to sinus rhythm might contribute to reduced atrial contractility.

LA pump function obtained by tissue Doppler echocardiography might be useful in routine clinical practice. For example, the clinical management of patients with paroxysmal AF might be improved by considering LA pump function before making a decision as to whether to pursue a strategy of rhythm control or rate control. It is possible that a rate-control strategy might be better in patients with poor LA pump function. Moreover, LA pump function might be useful to estimate the risk for LA thrombus formation and resulting thromboembolism, as reported previously.18

Study Limitations

We studied limited patients and the results should be applicable only in the population studied. Next, it is possible that LA volume and LAEF obtained by CT could have been affected by several factors such as LA reservoir and conduit functions, the volume loading condition and left ventricular diastolic function. We divided the entire RR interval into only 20 phases and measured maximum and minimum LA volumes, and this might lead to misidentification of LAEF. In addition, the motion of the mitral annulus is not entirely due to myocardial contraction, but rather is the summation of contraction, rotation and translation of the heart. Finally, like other Doppler-derived parameters, A’ is dependent on the Doppler angle and shows small beat-to-beat changes.

Conclusion

A’ is a simple, non-invasive and reliable method to estimate LA pump function that can be used in routine clinical practice. Measurement of A’ might improve the clinical management of cardiac patients.

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