Association Between Left and Right Atrial Remodeling With Atrial Fibrillation Recurrence After Pulmonary Vein Catheter Ablation in Patients With Paroxysmal Atrial Fibrillation

A Pilot Study

Yasushi Akutsu, MD, PhD; Kyouichi Kaneko, MD, PhD; Yusuke Kodama, MD, PhD; Jumpei Suyama, MD, PhD; Hui-Ling Li, MD, PhD; Yuji Hamazaki, MD, PhD; Kaoru Tanno, MD, PhD; Takehiko Gokan, MD, PhD; Youichi Kobayashi, MD, PhD

Background—Left atrial (LA) remodeling is a factor in atrial fibrillation (AF) recurrence after pulmonary vein catheter ablation (CA), but right atrium (RA) remodeling has not been investigated for possible associations to AF recurrence.

Methods and Results—Using 64-slice multidetector computed tomography, RA and LA volumes were measured 3-dimensionally before CA in 65 patients with initially proven idiopathic paroxysmal AF (mean age, 60±10 years, 81.5% men). The CA procedure was guided by CARTO Merge atrial electroanatomic mapping. Sixteen patients (24.6%) had AF recurrence within the 6-month period after the CA. The recurrence was associated with a large RA volume [odds ratio, 1.04; 95% confidence interval (CI), 1.02 to 1.07, \( P<0.0001 \)], a large LA volume with 1.04 [95% CI, 1.01 to 1.06, \( P=0.002 \)], and low LA mean voltage with 1.03 [95% CI, 1.01 to 1.05, \( P=0.002 \)]. After adjustment for potential confounding variables, RA and LA volumes remained predictive of AF recurrence. Large atrial volumes (mL) (RA \( \geq 87 \) or LA \( \geq 99 \)) predicted AF recurrence (sensitivity of RA volume: 81.3% in 13 of 16 patients with AF recurrence; specificity: 75.5% in 37 of 49 patients without AF recurrence; sensitivity of LA volume: 81.3% in 13 of 16 patients with AF recurrence; specificity: 69.4% in 34 of 49 patients without AF recurrence), and the combined estimate of both atrial volumes was incremental and additive prognostic power (sensitivity: 75% in 12 of 16 patients with AF recurrence; specificity: 93.9% in 46 of 49 patients without AF recurrence).

Conclusions—Both LA and RA remodeling are equally associated with post-CA AF recurrence. (Circ Cardiovasc Imaging. 2011;4:524-531.)

Key Words: atrial fibrillation ■ catheter ablation ■ multidetector computed tomography ■ right atrial remodeling

Radiofrequency percutaneous catheter ablation (CA) of atrial fibrillation (AF) with pulmonary vein (PV) isolation is currently the standard therapy for selected groups of patients and has been considered as a first-line therapy for patients symptomatic with paroxysmal AF, small left atrial (LA) dimensions, and no evidence of structural heart disease.\(^1\) However, a successful CA does not always maintain the sinus rhythm. LA atrial remodeling has been reported as a risk factor for AF recurrence after successful CA,\(^2\) although it is not clear that LA remodeling is the direct cause of AF recurrence or whether it is merely an associated condition. On the other hand, right atrium (RA) remodeling has also been reported in patients with paroxysmal AF.\(^3,5\) However, RA remodeling has not been focused on as a risk factor for AF recurrence because myocardial fibrosis due to LA remodeling and accompanying effects on critical circuits are considered to be the main cause of AF recurrence. In addition, the difficulty in accurate evaluation of RA remodeling may contribute to the LA focus. On the other hand, the incomplete closure of the oval fossa and the existence of interatrial muscular connections other than the Bachmann bundle are well-known points of contact between both atria. Recent studies demonstrated that both LA and RA fibrosis with remodeling occur in patients with AF, and the intra-atrial pressure that reflects atrial remodeling of both atria may be related to AF recurrence.\(^4,5\)

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Multidetector computed tomography (MDCT) allows multidimensional reconstruction of patient-specific cardiac anat-
Computed tomography–rendered volumes add a third dimension to an otherwise 2-dimensional ablation procedure, allowing better delineation of complex LA anatomy with precise volume estimation and increased electroanatomic mapping accuracy. Therefore, MDCT can more precisely assess the 3-dimensional shape of the atria than 2-dimensional echocardiography, particularly in the evaluation of RA volume.

We recently reported on the risk factors which perpetuated AF in patients with paroxysmal AF, but the risk factors for the transition from paroxysmal to permanent forms of AF are not the same as those for the late AF recurrence after intervention therapy. A recent report from a National Heart, Lung, and Blood Institute workshop has recommended research on the factors that influence secondary prevention delaying AF recurrence. We hypothesized that the magnitude of remodeling of both the LA and RA would be associated with AF recurrence after successful CA in patients with paroxysmal AF.

Methods

Study Population

We recruited patients with a history of palpitations who were initially diagnosed with paroxysmal AF at Showa University Hospital, Tokyo, Japan. Arrhythmia was diagnosed on the basis of documented AF by ambulatory ECG monitoring, 12-lead ECG, or Holter monitoring. A diagnosis of AF was made when visible the P waves on all 12 leads of the ECG were absent and an irregular random ventricular response was present. AF was considered paroxysmal if the fibrillatory process ended spontaneously after some seconds, minutes, hours, or up to 7 days. The left ventricular ejection fraction (LVEF) was measured by 2-dimensional echocardiography before the study. The anteroposterior LA dimension was measured from the parasternal long-axis using M-mode echocardiography. Any patient with an LVEF <50%, history of valvular disease including rheumatic cause, congenital heart disease, ischemic heart disease, and cardiomyopathy was excluded from this study. Patients were also excluded from this study if they had preexcitation syndrome, atrioventricular tachycardia or ventricular tachyarrhythmia, atrial flutter, or an implanted pacemaker before the start of the study. After application of the exclusion criteria, 65 patients (mean±SD; age, 60±10 years; 81.5% men) with paroxysmal AF who did not have structural heart disease were recruited for this study. Twelve normal healthy volunteers were also recruited as the control group (age, 57±14 years; 41.7% men). Sixty-four–slice MDCT scans of the patients was performed systematically up to 48 hours before the procedure, for electroanatomic mapping integration, PV anatomy delineation, and LA and RA volume estimations. All patients gave written informed consent before this study, and the protocol was approved by our institutional review board. Data collected prospectively included demographics, existing medical diagnoses, symptom, risk factors for vascular disease, medications, previous cardiac procedures, and history of vascular events.

Scan Protocol and Data Acquisition of MDCT

All patients were scanned with a 64-slice scanner (SOMATOM Sensation 64 Cardiac, Siemens Medical Solution, Forchheim, Germany) during stable sinus rhythm conditions and not tachyarrhythmia (<75 bpm). ß-Blockers were not used during the examinations. A bolus of contrast media (Omnipaque, 350 mg iodine/mL, Daiichi Sankyo Co, Ltd, Tokyo, Japan) was injected into the antecubital vein. The amount of the contrast media used for the scan was determined according to the patient’s body weight and scan time [the total dose= (scan time+4 seconds)×0.07×body weight]. The region of interest was placed within the ascending aorta, and the scan was started when the CT density was 150 Hounsfield units higher than the baseline CT. The scanning was performed in a single breath hold in the cranio-caudal direction from aortic arch to diaphragm. The scan was gated to the cardiac cycle through ECG synchronization with the following parameters: collimation width, 64×0.6 mm; rotation time, 330 ms; tube voltage, 120 kV; effective tube current, 800 mA; table feed, 11.5 mm/rotation; and pitch, 0.2 (radiation dose: 15.5±1.4 mSv). Image reconstruction was retrospectively gated to an ECG, and ECG-gated datasets were reconstructed with a slice thickness of 0.75 mm and a interval of 0.7 mm.
Table 1. Patient Characteristics and the Recurrence of AF After Pulmonary Vein Catheter Ablation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Recurrence of AF (n=16)</th>
<th>No Recurrence of AF (n=49)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>59±10</td>
<td>62±10</td>
<td>0.284</td>
</tr>
<tr>
<td>Male</td>
<td>15 (93.8%)</td>
<td>38 (77.6%)</td>
<td>0.147</td>
</tr>
<tr>
<td>History of smoking</td>
<td>2 (12.5%)</td>
<td>7 (14.3%)</td>
<td>0.857</td>
</tr>
<tr>
<td>History of diabetes</td>
<td>2 (12.5%)</td>
<td>7 (14.3%)</td>
<td>0.857</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>8 (50%)</td>
<td>23 (46.9%)</td>
<td>0.831</td>
</tr>
<tr>
<td>History of hyperlipidemia</td>
<td>6 (37.5%)</td>
<td>13 (26.5%)</td>
<td>0.402</td>
</tr>
<tr>
<td>Echocardiographic findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA dimension, mm</td>
<td>46.6±6.9</td>
<td>42.6±5.9</td>
<td>0.026</td>
</tr>
<tr>
<td>End-diastolic left ventricular dimension, mm</td>
<td>51.9±5.5</td>
<td>50.3±5.6</td>
<td>0.334</td>
</tr>
<tr>
<td>Left ventricular ejection fraction, %</td>
<td>59.3±6.4</td>
<td>62.8±6.5</td>
<td>0.064</td>
</tr>
<tr>
<td>Deceleration time, ms</td>
<td>206±49</td>
<td>205±46</td>
<td>0.938</td>
</tr>
<tr>
<td>Electroanatomic mapping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA mean voltage, mV</td>
<td>0.582±0.407</td>
<td>1.11±0.491</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No. of mapping points</td>
<td>115±23</td>
<td>107±35</td>
<td>0.390</td>
</tr>
<tr>
<td>Resting hemodynamics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting HR, bpm</td>
<td>66±7</td>
<td>66±9</td>
<td>0.55</td>
</tr>
<tr>
<td>Resting systolic BP, mm Hg</td>
<td>120±6</td>
<td>125±14</td>
<td>0.241</td>
</tr>
<tr>
<td>Resting diastolic BP, mm Hg</td>
<td>73±9</td>
<td>74±10</td>
<td>0.51</td>
</tr>
<tr>
<td>Laboratory data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRP, mg/dL</td>
<td>0.2±0.1</td>
<td>0.3±0.4</td>
<td>0.479</td>
</tr>
<tr>
<td>BNP, pg/mL</td>
<td>87.5±91.2</td>
<td>70.3±79.6</td>
<td>0.473</td>
</tr>
<tr>
<td>Medications before CA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of angiotensin-converting enzyme inhibitor</td>
<td>7 (43.8%)</td>
<td>15 (30.6%)</td>
<td>0.335</td>
</tr>
<tr>
<td>Use of β-blocker</td>
<td>3 (18.8%)</td>
<td>11 (22.4%)</td>
<td>0.755</td>
</tr>
<tr>
<td>Use of calcium channel antagonist</td>
<td>3 (18.8%)</td>
<td>14 (28.6%)</td>
<td>0.438</td>
</tr>
<tr>
<td>Use of digoxin</td>
<td>2 (12.5%)</td>
<td>9 (18.4%)</td>
<td>0.587</td>
</tr>
<tr>
<td>Use of diuretic drug</td>
<td>3 (18.8%)</td>
<td>3 (6.1%)</td>
<td>0.13</td>
</tr>
<tr>
<td>Use of sodium channel blocker</td>
<td>5 (31.3%)</td>
<td>19 (38.8%)</td>
<td>0.588</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; LA, left atrium; HR, heart rate; BP, blood pressure; CRP, serum concentration of C-reactive protein; BNP, plasma brain natriuretic peptide level; and CA, catheter ablation.

at the point of the cardiac cycle that corresponded to atrial end-diastole (≤330 ms before the QRS wave, Figure 1).

Both atrial volumes were measured using OsiriX software for the MacOS X operating system (version 3.3.2). OsiriX software allows the quantitative measurement of volume from 3-dimensional MDCT data. Each short-axis 0.7-mm interval CT image was examined, and the region of interest was defined on the LA and RA areas (Figure 2). Thus, RA and LA volumes were quantitatively calculated from 3-dimensional images, using OsiriX software. All measurements were performed by a blinded investigator without knowledge of the patient clinical histories.

Blood samples were obtained before injection of contrast media to measure C-reactive protein (CRP). CRP was assayed by a latex immunonephelometric method, with an assay range of 0.1 to 30 mg/dL, using an automatic analyzer (7350 Clinical Analyzer, Hitachi High-Tech Trading Co, Tokyo, Japan). The plasma brain natriuretic peptide (BNP) level was also measured using an immunoradiometric assay (Shionogi RIA, Shionogi Co Ltd, Osaka, Japan).

**PV Catheter Ablation**

The PV CA procedure was guided by CARTO Merge atrial electroanatomic mapping. The patients were submitted to complete isolation of the PVs by conventional procedures (wide antral circumferential PV isolation encircling the ipsilateral veins using radiofrequency energy). Before the CA, the LA voltage amplitudes were measured during sinus rhythm around the lesions that encircled both left- and right-side PVs to evaluate the degree of myocardial fibrosis. Radiofrequency energy was applied using a 3.5-mm irrigated-tip NAVISTER THERMOCOOL catheter (Biosense Webster Inc) with a temperature limitation of 42°C, radiofrequency energy up to 30 W, and 40-second duration. After the procedure, successful CA was confirmed in patients by PV stimulation.

**Follow-Up**

All patients had prospective follow-ups at least once every 4 weeks without antiarrhythmic drugs after the CA. AF recurrence was assessed from 1 month to 6 months, being defined as the presence of documented AF by 12-lead ECG and at least one 24-hour Holter monitoring to observe cardiac rhythm. Furthermore, 12-lead ECG and Holter monitoring were added during follow-up if the patients self-reported an irregular heartbeat or palpitations. The CA procedure was not repeated during follow-up in patients with AF recurrence.

**Statistical Analysis**

For descriptive purposes, the patients were divided into 2 groups on the basis of predictors such as LA or RA volume. All continuous variables are presented as mean±SD. Differences between groups (AF recurrence group, no recurrence group, and control group) were tested using an unpaired Student t test, χ² test, or Fisher exact test as appropriate. The associations between the predictors such as age, CRP, BNP, LVEF, LA dimension, LA mean voltage, and both atrial volumes and AF recurrence after CA were formally tested by multivariable logistic regression analysis. All multivariable analyses employed the forward stepwise method, with entry and removal probability values set at 0.5. A receiver operating characteristic (ROC) analysis was performed to define cutoff values, and the
cutoff values were defined by minimizing the expression of \((1 – \text{sensitivity})^2 + (1 – \text{specificity})^2\). The difference of ROC curve was compared from the area under curve (AUC), using the jackknife method. This analysis provided optimal sensitivity and specificity in predicting the AF recurrence after CA. Pearson correlation analysis and Bland-Altman plotting were performed to assess validity and reproducibility. The tolerance of variance inflation factor was calculated to evaluate the multicollinearity in the multiple regression analysis model. All statistical analysis was done using SPSS for windows version 11 (SPSS Inc, Chicago, IL). A probability value of \(<0.05\) was considered significant.

Results

Patient Characteristics

All patients were followed up during the 6-month period after CA, and a total of 16 patients had AF recurrence (24.6%). There were no significant differences between the patients with and without recurrence in age, sex, cardiovascular risk factors, and hemodynamic responses (Table 1). Diet-controllable factors such as obesity and hypertension were controlled by diet, salt restriction, and medication after entry into the study. On the 2-dimensional echocardiographs, LA dimension was larger \((P=0.026)\), and LVEF was lower but not significant \((P=0.064)\) in patients with AF recurrence than the patients without AF recurrence, but the end-diastolic left ventricular dimension and deceleration time were similar between those. The LA mean voltage was lower in patients with recurrence when compared with those not having a recurrence \((P<0.0001)\). There was no significant difference between the groups in inflammatory markers such as serum CRP concentration and the neurohumoral biomarker BNP. The use of medication before CA was not associated with AF recurrence. Both atrial volumes were larger in patients with AF than in the control group volunteers \((\text{LA}: 100\pm33 \text{ mL} \text{ versus } 60\pm17 \text{ mL}; \text{RA}: 83\pm36 \text{ mL} \text{ versus } 44\pm12 \text{ mL}; P<0.0001)\). Furthermore, both atrial volumes were larger in patients with AF recurrence than in patients without AF recurrence \((\text{LA}: 126\pm37 \text{ mL} \text{ versus } 91\pm27 \text{ mL}; \text{RA}: 118\pm41 \text{ mL} \text{ versus } 72\pm26 \text{ mL}; P<0.0001)\) (Figure 3).

LA and RA Volumes and LA Mean Voltage for Predicting AF Recurrence

RA and LA volumes on MDCT, LA mean voltage on the voltage mapping, and LA dimension on echocardiography were the primary factors associated with AF recurrence (Table 2). Each factor had no significant multicollinearity from the tolerance of variance inflation factor. In multivariable analysis, after adjustment for 7 potential confounding variables such as 4 significant factors from above, LVEF, age and BNP, RA and LA volume remained the primary predictors.
of AF recurrence (P=0.002 and P=0.008). The LA volume from MDCT was correlated with the mean LA voltage on the electroanatomic mapping (r=−0.422, P<0.0001), the RA volume from MDCT (r=0.404, P=0.001) (Figure 4), and the LA dimensions from echocardiography (r=0.691, P<0.0001).

The AUC for the predictions of AF recurrence was larger using RA volume than that of LA volume but not significant (0.85 versus 0.78, P=0.39) (Figure 5). When the cutoff values were at LA volume=99.4 mL and RA volume=87.6 mL, the sensitivity of a large LA volume (≥99 mL) for predicting AF recurrence was 81.3% in 13 of 16 patients, and the specificity was 69.4% in 34 of 49 patients without AF recurrence. The sensitivity of a large RA volume (≥87 mL) was 81.3% in 13 of 16 patients, and the specificity was 75.5% in 37 of 49 patients. Further, the sensitivity of low LA mean voltage (<0.7 mV) was 75% in 12 of 16 patients, and the sensitivity was 75.5% in 37 of 49 patients. When the atrial volumes were indexed to body surface area, the indexed both atrial volumes were also predictive of AF recurrence similarly (0.81 versus 0.71, P=0.30) (Figure 6).

After adjustment for potential confounding variables such as the LA mean voltage, large RA or LA volume remain the predictors of AF recurrence, with odds ratios of 13.4 [95% confidence interval (CI), 3.2 to 54.9] (P<0.0001), and 9.8, respectively [95% CI, 2.4 to 39.6] (P=0.001) (Table 3) (Figure 4). The large RA volume predicted AF recurrence in 13 of 25 patients (52%), whereas the large LA volume predicted in 13 of 28 patients (46.4%). Furthermore, the existence of both large atrium volumes predicted AF recurrence in 12 of 15 patients (80%). The combined measurements of both atrial volumes was a more powerful predictor than individual atrial volumes of the recurrence of post-CA AF, with an odds ratio of 46 [95% CI, 9 to 233.9, P<0.0001]. The combined atrial volumes had a sensitivity of 75% in 12 of 16 patients and a specificity of 93.9% in 46 of 49 patients.

**Reproducibility**

The reproducibility of atrial volume measurements on MDCT was tested in 40 randomly selected patients, and the agreement between the measurements was verified using the Bland-Altman method. The correlation between two measurements was excellent for both atrial volumes on MDCT, as shown in Figure 7 (LA volume: r=0.984, and RA volume: r=0.956; each P<0.0001). The 95% CI of bias included 0 for both atrial volumes, which demonstrated no fixed bias (95% CI of bias included 0 with −3.83 to 0.31 in LA volume and −5.97 to 1.73 in RA volume). The slope of bias for both

![Figure 5. Larger left (LA) and right atrial (RA) volumes, and LA mean voltage before catheter ablation (CA) for predicting AF recurrence. LA and RA volumes on multidetector computed tomography (MDCT), and LA mean voltage on electroanatomic mapping predicted AF recurrence after CA as shown in the receiver operating characteristics (ROC) curve. The area under curve (AUC) was larger using RA volume than that of LA volume, but not significant (0.85 versus 0.78, P=0.39).](image)

![Figure 6. Larger indexed left (LA) and right (RA) atrial volume (atrial volume/body surface area, BSA) before catheter ablation (CA) for predicting post-CA AF recurrence. The indexed LA and RA volumes on multidetector computed tomography (MDCT) also predicted AF recurrence after CA, as shown in the receiver operating characteristics (ROC) curve. The area under curve (AUC) was larger in the indexed RA volume than that of LA volume, but not significant (0.81 versus 0.71, P=0.30).](image)

Table 3. Prediction of the Recurrence of AF After Pulmonary Vein Catheter Ablation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Recurrence of AF (%)</th>
<th>Odds Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large LA volume ≥99 mL</td>
<td>13/28 (46.4%)</td>
<td>9.8 (2.4–39.6)</td>
<td>P=0.001</td>
</tr>
<tr>
<td>Low mean LA voltage &lt;0.7 mV</td>
<td>12/24 (50%)</td>
<td>9.3 (2.5–34.5)</td>
<td>P=0.001</td>
</tr>
<tr>
<td>Large RA volume ≥87 mL</td>
<td>13/25 (52%)</td>
<td>13.4 (3.2–54.9)</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Large LA ≥99 mL and RA volumes ≥87 mL</td>
<td>12/15 (80%)</td>
<td>46 (9–233.9)</td>
<td>P&lt;0.0001</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; CI, confidence interval; LA, left atrium; and RA, right atrium.

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For more information, please refer to the source indicated by the DOI at Circ Cardiovasc Imaging.
volumes was not significant, which indicates no proportional bias.

**Discussion**

**Atrial Remodeling for Predicting After CA AF Recurrence**

Together with age, LVEF, and hypertension, LA volume enlargement has been identified as an important risk factor of AF recurrence after cardioversion or CA. On the other hand, not only the LA size but also the RA size increases in patients with AF. Shin et al evaluated both the LA and RA dimensions for predicting the recurrence of AF over a 6-month period using echocardiography in AF patients. In contrast to the results of the present study, the results of the Shin et al study indicated that RA remodeling was less significant than LA remodeling for predicting AF recurrence. Their study may be limited in that they did not fully distinguish between paroxysmal AF and permanent AF. Paroxysmal AF is frequently a purely trigger-dependent phenomenon, whereas permanent AF is generally mechanically complex, implicating a more diffuse abnormality of the atrial substrate. Therefore, only patients with paroxysmal AF were evaluated for predicting AF recurrence in the present study. We found that in addition to LA remodeling, RA remodeling was also associated with the post-CA AF recurrence. This result indicates that the quantitative evaluation of atrium using 3-dimensional MDCT is an important tool for predicting AF recurrence because of the multivariate variation of the atrial volume. Helms et al demonstrated in a 12-month follow-up study of the both paroxysmal and permanent AF patients, using 3-dimensional MDCT that the sensitivity of large LA volumes (>135 mL) for predicting the recurrence of AF was 36%, and the specificity of such volumes was 96%. In the present study, the higher diagnostic accuracy of each atrial enlargement for predicting AF recurrence was obtained by quantitative 3-dimensional measurements in combination with a computer- and navigation-aided technique (OsiriX software). The combined LA and RA enlargements may better express more remarkable, overall structural remodeling than examination of individual atrial remodeling. These results suggest that a more accurate atrial remodeling would be estimated by measuring both atrial volume measurements.

**Relationship Between LA and RA Remodeling for AF Recurrence**

AF is known to be maintained by microreentrant sources located in the LA with fibrillatory conduction toward the RA. Verma et al demonstrated, using LA voltage mapping, that LA scar tissue was a predictor for post-CA AF recurrence, and LA scar tissue or fibrosis was closely related to other risk factors such as LA volume enlargement. Sanders et al and John et al showed the myocardial damage, as measured by voltage mapping, and the enlargement of atrial size between LA and RA in patients with paroxysmal lone AF were similar in magnitude. The same research group also showed a symmetrical change of electric remodeling between LA and RA in patients with rheumatic mitral stenosis, suggesting a potential cause of AF. Previously, the atrial
pacing or the ablation in the high right atrium, the interatrial septum, and Bachmann bundle had been used for the prevention of AF because multiple unstable reentrant circuits were observed in the RA.27–29 In the present study, the myocardial damage in the LA measured, as measured by voltage mapping, was closely associated with the magnitude of remodeling of both atria, suggesting a close relationship between both atria.

Kalifa et al5 demonstrated that the sources of rapid atrial activation during stretch-related AF were located in the PV region, and their level of spatio-temporal organization correlated to pressure. The high pressure in the PV junction and pulmonary hypertension may play an important role in AF recurrence. Furthermore, the previous study demonstrated that both RA and LA pressures were significantly and similarly increased in early and severe heart failure, and remodeling of both atria contributes to the development of atrial arrhythmia and pulmonary hypertension.30 The closure of the oval fossa is incomplete in 25% to 30% of subjects and is a source for paradoxical emboli.6 In addition, apart from the Bachman bundle, there are several muscular bridges that provide interatrial connections, such as the connections between the LA and the coronary sinus and those between the muscular sleeves of the right PVs and the RA.7 It is not known whether remodeling of both atria is a direct cause of AF recurrence. However, previous results and the results of the present study indicate that the occurrence of AF causes similar structural and electric remodeling in both atria, and the magnitude of the myocardial changes of both atrium influence post-CA AF recurrence as a result.31

In the present study, there was no significant difference in AUC for predicting AF recurrence between RA and LA volumes. An important feature of RA and LA remodeling is their propensity to coexist because one predisposes the heart to the other. More important, it is perceived that the combination of these conditions carries AF recurrence than either alone.

Study Limitations
In the present study, the small sample size, low event rates, and the relatively wide range of the odds ratio during logistic regression analysis are major limitations. Due to these limitations, and given the rarity of the disease, a large cohort study should be started in the near future to verify these findings. Furthermore, as a next step, the recovery from atrial remodeling (reverse remodeling) should be evaluated for the patients without AF recurrence after CA.

Except for individual patient risk factors such as atrial volume causing AF recurrence, the successful CA may be related to ablation lesion targeting the substrate-root line, mitral isthmus line, or ablation in complex fractionated electrograms. Therefore, different technical protocols or procedures may result in the different cut-off values of atrial volume for predicting the recurrence of AF.

Conclusion
Both LA and RA remodeling are equally associated with post-CA AF recurrence in patients with paroxysmal AF.

Disclosures
None.

References


**CLINICAL PERSPECTIVE**

Radiofrequency percutaneous catheter ablation (CA) of atrial fibrillation (AF) with pulmonary vein isolation is currently the standard therapy in patients with paroxysmal AF, and left atrial (LA) remodeling has been reported as a risk factor for AF recurrence after successful CA. Similarly, right atrium (RA) remodeling has also been reported in AF patients but has not been focused on as a risk factor for AF recurrence. In our study of 65 patients with paroxysmal AF, we observed similar structural and electric remodeling in both atria and demonstrate that both LA and RA remodeling as measured by cardiac CT were equally associated with post-CA AF occurring over a 6-month period after the CA. An important feature of RA and LA remodeling is their propensity to coexist because one predisposes the heart to the other. More important, it is perceived that the combination of these conditions carries AF recurrence than either alone.
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