Does Left Atrial Volume and Pulmonary Venous Anatomy Predict the Outcome of Catheter Ablation of Atrial Fibrillation?

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Does LA Volume and PV Anatomy Predict the Outcome of Catheter Ablation of AF.

Introduction: Preprocedural factors may be helpful in selecting patients with atrial fibrillation (AF) for treatment with catheter ablation and in making an assumption regarding their prognosis. The aims of this study were to investigate whether left atrial (LA) volume and pulmonary venous (PV) anatomy, evaluated by computed tomography (CT) prior to ablation, will predict AF recurrence following catheter ablation.

Methods and Results: We included 146 patients (mean age 57 ± 11 years, 83% male) with symptomatic AF (55% paroxysmal, 18% persistent, 27% long-standing persistent). All patients underwent CT scanning prior to catheter ablation to evaluate LA volume and PV anatomy. Circumferential PV isolation was performed guided by Cartomerge electroanatomical mapping. The outcome was defined as complete success, improvement, or failure.

After a mean follow-up of 19 ±7 months, complete success was achieved in 59 patients (40%), and 38 patients (26%) demonstrated improvement. LA volume was found to be an independent predictor of AF recurrence with an adjusted OR of 1.14 for every 10-mL increase in volume (95% CI 1.00–1.29, P = 0.047). PV variations were equally distributed among the different outcomes of the ablation procedure, and therefore univariate analysis did not identify PV anatomy as a predictor of outcome.

Conclusion: LA volume is an independent predictor of AF recurrence after catheter ablation. Additionally, PV anatomy did not have any effect on the outcome. These findings suggest that an assessment of LA volume may be incorporated into the preprocedural evaluation of patients being considered for AF ablation.

atrial fibrillation, catheter ablation, computed tomography, left atrium, pulmonary veins, recurrence

Introduction

Catheter ablation has emerged as an important treatment option for patients with atrial fibrillation (AF). However, there is a wide variety in success rates reported after catheter ablation and recurrences of AF remain an important problem. Prior studies have identified a number of predictors of outcome following AF ablation including age, type of AF, hypertension, sleep apnea syndrome, and left atrial (LA) diameter. We and others have recently shown that LA diameter, as assessed with conventional echocardiography, correlates poorly with true LA volume as determined by computed tomographic (CT) imaging. The purpose of this study, therefore, was to determine whether LA volume, as determined using CT imaging, predicts the outcome after catheter ablation of AF. We also sought to determine if specific patterns and variants of pulmonary venous (PV) anatomy might be predictive of the success or failure of AF ablation.

Methods

Patient Population

Patients with symptomatic AF referred to our center for treatment with catheter ablation between May 2005 and May 2007 were considered possible candidates for this study. Patients were enrolled if they were admitted for their first radiofrequency ablation procedure that involved circumferential PV isolation guided by Cartomerge electroanatomical mapping. Additional inclusion criteria were a cardiac CT prior to ablation for evaluation of LA and PV anatomy and a follow-up duration of minimum 6 months. The protocol was approved by the Institutional Review Board of the Johns Hopkins Medical Institutions and all patients provided informed consent.
Computed Tomography

Each patient underwent contrast-enhanced CT scanning within 24 hours of their ablation procedure using a 64-slice CT scanner (Aquilllon, Toshiba Medical Systems Corporation, Tochigi, Japan). CT scanning was achieved as reported in detail previously. Briefly, image acquisition was performed during one breath-hold at the end-expiratory phase after intravenous injection of 120–140 mL contrast media (Isovue, Bracco Diagnostics, Inc., Princeton, NJ, USA) at an infusion rate of 3 mL/sec. The duration of scanning was approximately 10 seconds and scanning was retrospectively gated to the cardiac cycle.

CT images were reconstructed every 10% of the cardiac cycle with a slice thickness of 1 mm. The reconstructed images were transferred to a commercially available workstation (Vitrea 2, Vital images, Minneapolis, MN, USA) for evaluation of LA and PV anatomy. Eighty patients (54.8%) were in sinus rhythm during scanning and the phase corresponding with the end-diastole of the atria, just before mitral valve opening, was selected for evaluation. Sixty-five patients (44.5%) were in AF and one patient (0.7%) experienced atrial flutter during image acquisition. In these patients, the phase that appeared to have the largest LA volume was selected for assessment.

Image Analysis

Image analysis was performed by a single investigator in a blinded fashion with the selected phase of the cardiac cycle and the Vitrea 2 workstation.

First, LA volume was calculated. The method to measure LA volume used in this study has been used in prior studies with both CT and magnetic resonance imaging (MRI) as imaging techniques. This method has shown to be very closely related to true LA size as obtained by postmortal assessment (r = 0.99). The LA area was manually traced, as demonstrated in Figure 1, on each cross-sectional image of the CT scan from the roof of the LA to the level of the mitral annulus. PVs were excluded at their ostia and the LA appendage was excluded at its base. The mitral annulus was taken to be the atrioventricular border, and therefore the mitral annulus was excluded at the point of insertion of the mitral valve leaflets. LA areas were automatically calculated and summed to obtain LA volume. Twenty random blinded reassessments were performed to determine intraobserver variability. A mean difference between first and second assessment was reported of 2.7 ± 1.7%, ranging from 0% to 6.0%.

Second, PV anatomy was evaluated. The number and distribution of PVs were recorded for each patient, including the left and right superior PV, the left and right inferior PV, and the presence of PV variations, for example a common left or right trunk, and left- or right-sided accessory PVs (Fig. 2). A common trunk was defined as a superior and inferior PV that join proximal to the LA resulting in a single atriopulmonary venous junction. An accessory PV has its own independent atriopulmonary venous junction separate from the superior and inferior PVs and is named for the pulmonary lobe or segment that it drains.

Catheter Ablation Procedure and Patient Follow-Up

The approach employed for catheter ablation of AF at Johns Hopkins Hospital has been previously reported. A wide area circumferential approach was used with a primary endpoint of PV isolation as assessed using a circular multielectrode mapping catheter (Lasso, Biosense Webster, Inc., or Orbiter PV, Bard Electrophysiology, Lowell, MA, USA).

Each patient was seen in the outpatient clinic 3 months following the ablation procedure, and at this visit rhythm status was determined using history and ECG. If patients had symptoms suggesting the presence of PV stenosis, a CT or MRI was acquired to evaluate these symptoms.
Antiarrhythmic drug therapy was continued for at least 2 months following catheter ablation and was discontinued thereafter in patients who became free of AF during follow-up. When patients reported symptoms suggestive of AF recurrence during follow-up, event monitoring was performed. Since many included patients did not live in close proximity to this region of the country, they were allowed follow-up through their local cardiologist. Therefore, long-term follow-up data were obtained by direct telephone interview of all patients.

The following definitions were used in the present study. Complete success was defined as recommended by the HRS Consensus Document on AF ablation as the absence of AF or any other atrial tachyarrhythmias lasting 30 seconds or longer, off antiarrhythmic drug therapy. The first 3 months following ablation was a blanking period during which AF recurrences were not evaluated. Improvement was defined as either ≥90% reduction of AF burden with no antiarrhythmic drug therapy or the absence or ≥90% reduction of AF burden while receiving previously ineffective antiarrhythmic drugs, after the blanking period. Clinical success was determined by combining the patients with complete success and improvement. Failure was defined as failure to achieve either endpoint.

Statistical Methods

Statistical analysis was performed using SPSS 16.0 (SPSS, Chicago, IL, USA). Data are expressed as mean ± standard deviation, counts, or percentages, as appropriate. Intraobserver variability was determined by calculating the mean difference between the first and the second measurement. Univariate and multivariate analyses were performed to identify predictors of outcome of catheter ablation. In univariate analysis, an independent t-test was used for continuous variables analysis and a chi-square test was used for discrete variables analysis. Variables tested in the univariate analysis were selected for multivariate analysis, which was performed with a logistic regression analysis. A P-value <0.05 was considered statistically significant.

Results

Patient Characteristics

The patient population comprised 146 patients with symptomatic AF who underwent catheter ablation and met the enrollment criteria for this study. The baseline patient characteristics are summarized in Table 1. Most patients were male (121 patients, 83%). The mean age was 57 ± 11 years. Paroxysmal AF was present in 80 patients (55%). The remaining patients had either persistent AF (26 patients, 18%) or longstanding persistent AF (40 patients, 27%). Long-standing persistent AF was defined as continuous AF of greater than 1-year duration.

Outcome of Catheter Ablation

The mean follow-up duration of the study population was 19 ± 7 months. A repeat procedure was performed in 15 patients (10%) because of recurrences of AF. At the end of the follow-up period, complete success was achieved in 59 patients (40%) and 38 patients (26%) met the definition of improvement. These 97 patients (66%) demonstrated clinical improvement. Failure was defined as failure to achieve either endpoint. Catheter ablation was unsuccessful in 49 patients (34%).

Left Atrial Volume and Pulmonary Venous Anatomy

The mean LA volume in the total study population was 127 ± 39 mL with a range of 63–270 mL. LA volume was significantly smaller in patients with paroxysmal AF than that in patients with persistent or longstanding persistent AF. 114 ± 33 mL versus 133 ± 33 mL (P = 0.01) and 150 ± 42 mL (P < 0.001), respectively. LA volume was not influenced by the duration of AF prior to catheter ablation (P = 0.42).

With regard to the PV anatomy, conventional PV anatomy, with 4 separate PVs, was present in 86 patients (59%) (Table 2). The remaining patients had a PV variation. The most common observed PV variation was a right-sided middle accessory PV in 34 patients (23%), and the second most frequent PV variation was a common left trunk, which was present in 24 patients (16%). No patients had a left accessory PV, and only one patient (0.7%) had a common right trunk.

Predictors of Recurrence of Atrial Fibrillation

Univariate and multivariate analyses were performed to identify whether LA volume predicts the outcome of catheter ablation. The outcome was divided into patients without recurrences of AF (complete success) and patients with recurrences of AF (improvement or failure) following catheter ablation. Variables selected for univariate analysis were

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Baseline Patient Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>146</td>
</tr>
<tr>
<td>Age (years)</td>
<td>57 ± 11</td>
</tr>
<tr>
<td>Male gender</td>
<td>121 (83%)</td>
</tr>
<tr>
<td>Type of AF</td>
<td>Paroxysmal 80 (55%); Persistent 26 (18%); Longstanding persistent 40 (27%)</td>
</tr>
<tr>
<td>Duration of AF (years)</td>
<td>7 ± 6</td>
</tr>
<tr>
<td>Ineffective AADs</td>
<td>1.5 ± 0.9</td>
</tr>
<tr>
<td>Structural heart disease</td>
<td>35 (24%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>68 (47%)</td>
</tr>
</tbody>
</table>

Values are given as mean ± standard deviation or number (percent). AAD = antiarrhythmic drug; AF = atrial fibrillation.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Distribution of Pulmonary Venous Anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern of PV anatomy</td>
<td>Prevalence</td>
</tr>
<tr>
<td>Conventional anatomy*</td>
<td>86 (59%)</td>
</tr>
<tr>
<td>Common left trunk</td>
<td>24 (16%)</td>
</tr>
<tr>
<td>Common right trunk</td>
<td>1 (0.7%)</td>
</tr>
<tr>
<td>Left-sided accessory PVs</td>
<td>0</td>
</tr>
<tr>
<td>Right-sided accessory PVs</td>
<td>40 (27%)</td>
</tr>
<tr>
<td>Superior accessory PV</td>
<td>6 (4%)</td>
</tr>
<tr>
<td>Middle accessory PV</td>
<td>34 (23%)</td>
</tr>
<tr>
<td>Multiple middle accessory PVs</td>
<td>2 (1.4%)</td>
</tr>
<tr>
<td>Inferior accessory PV</td>
<td>0</td>
</tr>
</tbody>
</table>

Values are given as number (percent).

*Conventional anatomy = single right and left superior and inferior pulmonary veins that drain into the left atrium without accessory veins. PV = pulmonary vein/venous.
Table 3

Predictors of Recurrence of Atrial Fibrillation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Univariate Analysis</th>
<th>Multivariate Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-Value</td>
<td>P-Value</td>
</tr>
<tr>
<td>Age</td>
<td>0.596</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>0.688</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.130</td>
<td></td>
</tr>
<tr>
<td>Structural heart disease</td>
<td>0.102</td>
<td></td>
</tr>
<tr>
<td>Type of AF</td>
<td>0.820</td>
<td></td>
</tr>
<tr>
<td>Duration of AF</td>
<td>0.024</td>
<td>0.038</td>
</tr>
<tr>
<td>LA volume</td>
<td>0.020</td>
<td>0.047</td>
</tr>
<tr>
<td>Conventional PV anatomy</td>
<td>0.198</td>
<td></td>
</tr>
<tr>
<td>Common left trunk</td>
<td>0.133</td>
<td></td>
</tr>
<tr>
<td>Right-sided middle accessory PV</td>
<td>0.917</td>
<td></td>
</tr>
<tr>
<td>Right-sided superior accessory PV</td>
<td>0.625</td>
<td></td>
</tr>
</tbody>
</table>

A P-value < 0.05 (highlighted in bold) was considered statistically significant.

AF = atrial fibrillation; LA = left atrial; PV = pulmonary vein/venous.

The distribution of LA volume among the different outcomes of the ablation procedure is shown in Figure 3. Patients with complete success had a mean LA volume of 118 ± 32 mL, patients who met the definition of improvement had a mean LA volume of 132 ± 35 mL, and patients who failed the ablation procedure had a mean LA volume of 135 ± 47 mL. Among the 10 patients with a LA volume of greater than 200 mL, complete success was achieved in 2 patients (20%). In contrast, complete success was achieved in 7 of 22 patients (32%) with a LA volume between 150 and 200 mL and in 50 of 114 patients (44%) with a LA volume less than 150 mL.

The impact of PV anatomy on the outcome of catheter ablation of AF was also evaluated. Patients were categorized into those with a conventional PV anatomy, a common left trunk, and right-sided middle and superior accessory PVs. PV variations were equally distributed among the different outcomes of the ablation procedure. Univariate analysis did not identify PV anatomy as a predictor of outcome after AF ablation (Table 3).

Discussion

The aims of the present study were to investigate whether LA volume and PV anatomy predict the outcome of AF ablation. The results of our study revealed that LA volume is an independent predictor of recurrences of AF after AF ablation with an adjusted odds ratio of 1.14 for every 10-mL increase in volume. Additionally, PV anatomy did not have any effect on the outcome of catheter ablation of AF. PV variations were equally distributed among patients with AF recurrence or no AF recurrence.

To the best of our knowledge, this is the first study to evaluate whether true LA volume, as measured by manually tracing the LA area on CT prior to ablation, predicts the outcome of catheter ablation of AF. In contrast, a number of studies have evaluated LA diameter, as assessed with conventional echocardiography, as a predictor of outcome of AF ablation. The results of these studies are contradictory. Some studies reported LA diameter by echocardiography to be an independent predictor of AF recurrence following catheter ablation.2,3,5 However, other studies reported opposing results.4,21,22

There have been 2 prior studies that have examined the relationship between LA volume and the outcome of AF ablation. Shin and colleagues used echocardiography to measure LA volume and reported that LA volume was a predictor of AF recurrence after catheter ablation (P = 0.01).23 In addition, Maciel et al. used the CARTO system to determine LA volume. They also identified LA volume to be an independent predictor of AF recurrence (P < 0.001).24 Consistent with the studies of Shin et al. and Maciel et al., LA volume was identified as an independent predictor of outcome following AF ablation in our study. It is reassuring that the results are steady and consistent with the two prior studies that have assessed LA volume with echocardiography and electroanatomic mapping. The consistency of the reported relationship between LA volume, regardless of how assessed, is striking. This is particularly true when contrasted with the varying results of studies that have evaluated the relationship of LA diameter, as assessed with conventional echocardiography, with the outcome after AF ablation.

Surprisingly, LA volume prior to catheter ablation was correlated with the outcome and AF type; however, univariate analysis did not identify AF type as a predictor of outcome. This is striking because many studies have found AF type to be associated with the outcome of catheter ablation, reporting a higher success rate in patients with paroxysmal
AF compared to patients with persistent AF. The similar success rates found in patients with different AF types within our study population may be explained by the small number of patients within the subgroups or the association of AF type with other predictors of outcome. Additionally, several other studies could not confirm a relationship between AF type and the outcome of catheter ablation as well.2,6,28 For instance, Cheema and colleagues reported a success rate of 48%, 36%, and 50% in patients with paroxysmal, persistent, or permanent AF, respectively (P = 0.90).26

Furthermore, our study examined for the first time the relationship between PV anatomy and the outcome of AF ablation. The distribution of anatomical variants of PV anatomy in our study is very consistent with prior studies that have reported that four distinct PV ostia are present in approximately one-half to two-thirds of patients and that the remaining patients have one or more anatomical variants. The relationship between PV anatomy and the outcome of AF ablation. The results of our study did not find PV anatomy to be predictive of outcome.

Conclusion

The results of the present study demonstrate that LA volume is an independent predictor of outcome following AF ablation. For each 10 mL increase in volume the risk of AF recurrence increased by 14%. This finding, together with the results of prior studies, suggests that an assessment of LA volume may be incorporated into the preprocedural evaluation of patients being considered for AF ablation to be able to make an assumption regarding their prognosis. In addition, LA volume assessments should also be included as a covariate in future clinical trials of AF ablation.

References

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