The association of baseline left atrial structure and function measured with cardiac magnetic resonance and pulmonary vein isolation outcome in patients with drug-refractory atrial fibrillation

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BACKGROUND Prognostic significance of left atrial (LA) function in patients with atrial fibrillation (AF) is poorly defined.

OBJECTIVE To examine the association of LA function measured with cardiac magnetic resonance (CMR) feature-tracking and AF recurrence following catheter ablation.

METHODS One hundred and twenty-one AF patients (72% paroxysmal, mean age 59 ± 10 years) were enrolled. Baseline LA function was measured by calculating passive, active, and total emptying fractions (LAEF) and analysis of global longitudinal strain and strain rates. Patients were followed up for recurrence of AF or atrial tachycardia (AT). Hazard ratios for recurrence were calculated using Cox proportional models adjusted for potential clinical confounders, type of AF, left ventricular ejection fraction, AF duration, LA volume, and late gadolinium enhancement (LGE).

RESULTS During a mean follow-up of 18 ± 9 months, 52 patients (43%) experienced recurrent AF/AT. Patients with recurrent AF/AT had higher baseline LA volume index and lower LA passive, and total LAEF ($P < .05$ for all). The baseline peak LA strain and strain rates in all phases of LA function were lower in the AF/AT recurrence group ($P < .01$ for all). In multivariable analysis total LAEF, peak LA strain, and systolic and late diastolic strain rates were associated with recurrence. Both peak LA strain and total LAEF improved prediction of recurrent AT/AF compared to the baseline clinical model, including LA LGE (C statistic 0.82 vs 0.77, $P < .05$ for both total LAEF and peak LA strain).

CONCLUSIONS LA reservoir function was independently associated with recurrent AF/AT after PVI and can additionally improve risk stratification in patients undergoing PVI.

KEYWORDS Pulmonary vein isolation; Cardiac MRI; Left atrial function; Left atrial fibrosis

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Introduction

Percutaneous catheter ablation of the left atrium (LA) to encircle the pulmonary veins (pulmonary vein isolation; PVI) is an established method to maintain sinus rhythm in patients with symptomatic atrial fibrillation (AF). Despite advances in ablation techniques, the recurrence rate remains substantial.[1,2] Therefore identifying methods to risk-stratify AF patients undergoing catheter ablation is of great clinical value.

Several clinical parameters have been shown to predict arrhythmia recurrence after PVI. These include age, sex, left ventricular ejection fraction (LVEF), hypertension, diabetes mellitus, obstructive sleep apnea, nonparoxysmal AF, and LA size.[3–6] Additionally, LA function has been used to identify patients at higher risk of recurrence.[7–9] In the majority of recent studies, speckle-tracking echocardiography has been used for the assessment of LA function. However, given the anatomic location and the thin wall of

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LA, echocardiographic assessment of LA function can be challenging. On the other hand, cardiac magnetic resonance (CMR) with a higher spatial resolution is the gold-standard modality for the assessment of myocardial motion. More recently, feature-tracking magnetic resonance imaging (MRI) has been successfully used to assess LA functional parameters with high reproducibility.[10] In this study we sought to examine the association of phasic LA function measured with the novel technique of feature-tracking CMR and AF recurrence after PVI. We hypothesized that poor LA function at baseline would be associated with AF recurrence after PVI.

Methods

Study population

The Johns Hopkins Institutional Review Board approved the study and all patients provided written informed consent. Between January 2011 and September 2013 all consecutive patients with drug-refractory symptomatic AF undergoing CMR at Johns Hopkins Hospital for definition of pulmonary vein anatomy prior to AF ablation who agreed to participate in our registry were enrolled. The study cohort included patients undergoing first-time radiofrequency ablation who were in sinus rhythm at the time of CMR. In order to assess both LA passive and active functions, patients who were in AF at the time of MRI were excluded.

CMR protocol

Images were acquired using 1.5 Tesla scanners (Avanto and Aera; Siemens, Erlangen, Germany), a 6-channel–phased array body coil in combination with a 6-channel spine matrix coil. Cine CMR images were obtained in standard horizontal (4-chamber) and vertical (2-chamber) long axis planes using a retrospective electrocardiogram(ECG)-gated steady-state free precession sequence with the following parameters: typical repetition time/echo time of 3.0/1.5 msec, slice thickness 8 mm, spacing 2 mm, flip angle 78º, field of view 36–40 cm, and typical in-plane resolution and temporal resolution of 1.5 × 1.5 mm and 30–40 msec, respectively. Late gadolinium enhancement CMR (LGE-CMR) images were acquired within a range of 15–25 minutes (mean 18.8 ± 2.4 minutes) after a gadolinium injection (0.2 mmol/kg; gadopentetate dimeglumine; Bayer Healthcare Pharmaceuticals, Montville, NJ) using a fat-saturated 3-dimensional inversion recovery prepared fast spoiled gradient recalled echo sequence with respiratory navigation and ECG gating, echo time of 1.52 ms, repetition time of 3.8 ms, in-plane resolution of 1.3 × 1.3 mm, slice thickness of 2.0 mm, and flip angle of 10º. Trigger time for 3-dimensional LGE-CMR images was optimized to acquire imaging data during diastole of LA as observed from the cine images. The optimal inversion time was identified with an inversion time scout scan (median 270 ms; range 240–290 ms) to maximize nulling of the LA myocardium.

LA functional analysis

Multimodality Tissue Tracking software (version 6.0; MTT, Toshiba, Japan) was used to measure phasic LA volumes, strain, and strain rate from 4-chamber and 2-chamber cine CMR images, which were obtained before catheter ablation. The methods have been described and validated previously with excellent reproducibility.[10] An experienced operator, blinded to the outcome status of the patients, contoured endocardial and epicardial LA borders in 2- and 4-chamber cine CMR images. Once contouring is complete in one phase, the software automatically tracks on screen pixels during the cardiac cycle (Video 1; supplemental material available online). Using the volume/time curves, measurements for maximum LA volume (LAV_{max}), LA volume before LA contraction ($LAV_{pre\text{-}a}$), and minimum LA volume (LAV_{min}) were extracted (Figure 1). LA total, passive, and active emptying fractions were then calculated as follows:

- Passive LA emptying fraction (Passive LAEF): $100 \times (LAV_{max} - LAV_{pre\text{-}a})/LAV_{max}$
- Active LA emptying fraction (Active LAEF): $100 \times (LAV_{pre\text{-}a} - LAV_{min})/LAV_{pre\text{-}a}$
- Total LA emptying fraction (Total LAEF): $100 \times (LAV_{max} - LAV_{min})/LAV_{max}$

Global longitudinal strain and strain rate curves were generated by averaging longitudinal strain and strain rate measurements in all LA segments, as shown in Figure 1.

Quantification of LA enhancement

Our method of LA delayed enhancement measurement has been described in detail previously.[10,11] In summary, we used the image intensity ratio, defined as the mean pixel intensity of each sector divided by the mean pixel intensity of the entire LA blood pool. A threshold of 0.97, which previously was shown to be correlated to a bipolar voltage of <0.5 mV, was used for LA enhancement determination.

PVI protocol

Details of the PVI techniques at our institution have been described previously.[12] An endocardial map of the LA was created with an electroanatomic mapping system (CARTO; Biosense Webster, Diamond Bar, CA) and superimposed upon the pre-existing CMR image of the chamber. Radiofrequency catheter ablation using the PVI strategy was performed with a 3.5-mm open-irrigation tip (Navistar Thermocool; Biosense Webster) in all cases. The electrical isolation was confirmed by a circular multipolar electrode mapping catheter (Lasso; Biosense Webster). Acute PVI was achieved in all subjects. In persistent AF cases, the ablation procedure also included a linear LA roofline. The cavotricuspid isthmus was ablated if atrial flutter could be induced or was previously documented. Patients who were still in AF at the end of the procedure were electrically cardioverted.