Association of left atrial function with incident atypical atrial flutter after atrial fibrillation ablation

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BACKGROUND Symptomatic left atrial (LA) flutter (LAFL) is common after atrial fibrillation (AF) ablation.

OBJECTIVE The purpose of this study was to examine the association of baseline LA function with incident LAFL after AF ablation.

METHODS The source cohort included 216 patients with cardiac magnetic resonance (CMR) before initial AF ablation between 2010 and 2013. Patients who underwent cryoballoon or laser ablation, patients with AF during CMR, and those with suboptimal CMR, or missing follow-up data were excluded. Baseline LA volume and function were assessed by feature-tracking CMR analysis.

RESULTS The final cohort included 119 patients (mean age 58.9 ± 11 years; 76.5% men; 70.6% patients with paroxysmal AF). During a median follow-up of 421 days (interquartile range 235–751 days), 22 patients (18.5%) had incident LAFL. Baseline LA volume was similar between the 2 groups. In contrast, baseline reservoir, conduit, and contractile function of the LA were significantly impaired in patients with incident LAFL. Baseline global peak longitudinal atrial strain (PLAS) $<$22.65% predicted incident LAFL with 86% sensitivity and 68% specificity (C statistic 0.76). In a multivariable model adjusting for age, heart failure, and LA volume, PLAS (hazard ratio 0.9 per % increase in PLAS; $P = .003$) and LA linear lesions (hazard ratio 2.94; $P = .020$) were independently associated with incident LAFL. The coexistence of PLAS $<$22.65% and linear lesions was associated with 9-fold increased hazard of incident LAFL.

CONCLUSION Baseline LA function and linear lesions were independently associated with incident LAFL after AF ablation. Linear lesions should be limited to selected cases, especially in patients with impaired LA function.

KEYWORDS Atrial fibrillation; Atrial flutter; Cardiac magnetic resonance; Left atrium; Pulmonary vein isolation

ABBREVIATIONS **AF** = atrial fibrillation; **CFAE** = complex fractionated atrial electrogram; **CMR** = cardiac magnetic resonance; **IQR** = interquartile range; **LA** = left atrium/atrial; **LAFL** = left-sided atrial flutter; **LGE** = late gadolinium enhancement; **PLAS** = peak longitudinal left atrial strain; **PVI** = pulmonary vein isolation; **SR-ed** = peak early diastolic left atrial strain rate; **SR-ld** = peak late diastolic left atrial strain rate; **SR-s** = systolic left atrial strain rate

(Heart Rhythm 2016;13:391–398)

Introduction

Atrial fibrillation (AF) is the most common arrhythmia and is associated with significant symptoms and mortality.[1] Catheter-based AF ablation has become a well-established management strategy for symptomatic AF.[2] Despite technological advances in AF ablation, evolving strategies, and experience, arrhythmia recurrences remain relatively high.[3,4] Left-sided atrial flutter (LAFL) accounts for a substantial proportion of symptomatic sustained recurrences after AF ablation.[2,5–8] Previous studies[2,7–10] have reported clinical and procedure-related risk factors for postablation LAFL, including linear lesions, incomplete pulmonary vein isolation (PVI), persistent AF, and structural heart disease.

In recent years, feature-tracking cardiac magnetic resonance (CMR) has emerged as a sophisticated tool for a detailed chamber-specific functional analysis.[11] It has been shown that left atrial (LA) function predicts recurrences after AF ablation.[12] In this study, we aimed to define feature-

The study was funded by the National Institutes of Health (grant nos. K23HL089333 and R01HL116280) as well as by a Biosense Webster grant to Dr Nazarian; the Roz and Marvin H. Weiner and Family Foundation; the Dr. Francis P. Chiaramonte Foundation; Marilyn and Christian Poindexter; and the Norbert and Louise Grunwald Cardiac Arrhythmia Research Fund. Dr Nazarian is a scientific advisor to Medtronic, CardioSolv, and Biosense Webster as well as a principal investigator for research funding to Johns Hopkins University from Biosense Webster. **Address reprint requests and correspondence:** Dr Saman Nazarian, Division of Cardiology, Department of Medicine, Johns Hopkins University, Halsted 576, 600 N Wolfe St, Baltimore, MD 21287. E-mail address: snazarian@jhmi.edu.

1547-5271/$-see front matter http://dx.doi.org/10.1016/j.hrthm.2015.09.028

tracking CMR-derived LA functional characteristics of patients who had LAFL after AF catheter ablation.

Methods

Study population

The source cohort included 216 consecutive patients with AF who underwent CMR before initial AF ablation between 2010 and 2013. Of these, 37 patients were excluded because of cryoballoon or laser ablation. Patients with AF at the time of CMR (n = 46), suboptimal/missing cine images (n = 8), and missing follow-up data (n = 6) were also excluded. Clinical characteristics of the final cohort, which included 119 patients, were extracted by review of electronic medical records. The Johns Hopkins Institutional Review Board approved the study, and all participants provided written informed consent.

CMR protocol

Preprocedural (average 4 days before ablation) CMR was performed using a 1.5-T MRI scanner (Avanto and Aera, Siemens, Erlangen, Germany) equipped with a phased array cardiac coil. Vertical and horizontal long-axis cine CMR was performed using a steady-state free precession sequence (minimal repetition time/ echo time, 8-mm slice thickness, 2-mm spacing, 78° flip angle, and 36–40 cm field of view) with 1.5 × 1.5 mm in-plane resolution.

Feature-tracking CMR

The Multimodality Tissue Tracking (MTT; version 6.0, Toshiba, Japan) software was used to measure phasic LA volumes, strain, and strain rate on vertical and horizontal long-axis cine images. After manual contouring of end-systolic endocardial and epicardial LA borders, the software automatically tracked pixel features within the tissue throughout the cardiac cycle, as described previously.[13] In all cases, pulmonary veins and LA appendage were excluded from the contours. Manual adjustments were performed when tracking was suboptimal. The software generated a volume curve for each phase by using the biplane area-length method (Figure 1). Maximum, precontraction, and minimum LA volumes were obtained from the phasic volume curve to calculate the following functional parameters:

- Total LA emptying fraction: 100 × (maximum LA volume – minimum LA volume)/maximum LA volume
- Passive LA emptying fraction: 100 × (maximum LA volume – precontraction LA volume)/maximum LA volume
- Active LA emptying fraction: 100 × (precontraction LA volume – minimum LA volume)/precontraction LA volume

Global LA longitudinal strain and strain rate were calculated as the mean longitudinal strain and strain rate of all segments (Figure 1). Peak longitudinal LA strain (PLAS), systolic LA strain rate (SR-s), peak early diastolic LA strain rate (SR-ed), and peak late diastolic LA strain rate (SR-ld) were measured. SR-ed and SR-ld were presented as absolute values. Reservoir function was represented by PLAS, SR-s, and total LA emptying fraction; conduit function was represented by passive LA emptying fraction and SR-ed; and contractile function was represented by SR-ld and active LA emptying fraction. We previously reported on the reproducibility of CMR-derived LA functional parameters using the MTT software.[14]

Catheter ablation

All patients underwent radiofrequency ablation as described previously.[15] After obtaining double atrial transseptal puncture, electroanatomic mapping (CARTO, Biosense Webster Inc, Diamond Bar, CA) of the LA endocardium was performed with registration onto a previously acquired CMR image. A 3.5-mm irrigated tip catheter (ThermoCool, Biosense Webster) was used for mapping and ablation. A circular multipolar electrode mapping catheter (Lasso, Biosense Webster) was used to confirm PVI by the presence of entrance and exit block. Additional linear lesion sets, connecting the right and left pulmonary venous antra across the LA roof, floor, or posterior wall, and complex fractionated atrial electrogram (CFAE) ablation procedures were performed per operator discretion. High-frequency stimulation for the identification of ganglionated plexi was not performed. However, transient >50% prolongation of the RR interval and sudden >20 mm Hg transient decreases in systolic radial artery pressure were noted as vagal responses consistent with ganglionated plexus ablation. Repeat PVI was performed during follow-up, depending on symptoms and clinician's preference. During the repeat procedure, the diagnosis and characteristics of LAFL were confirmed by activation and entrainment mapping. Sites with fractionated potentials that participated in the LAFL circuit were targeted for ablation.

Follow-up

After the procedure, patients were observed for 24 hours. In the absence of AF recurrence, preprocedurally ineffective antiarrhythmic medications were discontinued after 3 months. Symptom-prompted 24-hour Holter monitoring and scheduled electrocardiography at 3, 6, and 12 months were performed. *Incident LAFL* was defined as symptomatic or asymptomatic documented LAFL >30 seconds in duration. In the absence of electrophysiology study, an LAFL diagnosis was made on the basis of agreement between the 2 expert reviewers masked to clinical and imaging information. The readers diagnosed LAFL if (1) high-frequency (180–260 ms) F waves with continuous oscillation without a flat baseline were noted and (2) the F-wave morphology was not suggestive of typical cavotricuspid isthmus–dependent AFL (sawtooth pattern in inferior leads, positive F waves in lead V_1, and isoelectric or negative in leads V_5-V_6). Patients without LAFL were censored at the time of last available follow-up.