JACC: CLINICAL ELECTROPHYSIOLOGY
VOL. ■, NO. ■, 2017

ISSN 2405-500X/$36.00
PUBLISHED BY ELSEVIER
http://dx.doi.org/10.1016/j.jacep.2017.07.016

The Spatial Distribution of Late Gadolinium Enhancement of Left Atrial MRI in Patients With Atrial Fibrillation

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ABSTRACT

OBJECTIVES The purpose of this study is to evaluate the spatial distribution of late gadolinium enhancement (LGE) of the left atrium (LA) by LGE-magnetic resonance imaging in an atrial fibrillation (AF) population.

BACKGROUND LGE of the LA can be a surrogate of pre-existing structural remodeling of LA.

METHODS LGE-magnetic resonance imaging scans were used for 160 patients with AF (mean age 66 ± 11 years) before AF ablation. To know the spatial distribution of LGE, the extent of LGE in 6 LA subregions was examined. Overall LGE distribution was also summarized as a spatial frequency histogram using an atlas of LA shape. These data were also compared between paroxysmal AF (87 patients) and persistent AF (73 patients).

RESULTS LGE coverage (%) in each subregion was as follows: 41.8 ± 18.9% in the left pulmonary vein (PV) antrum, 27.1 ± 16.7% in the left lateral wall, 25.8 ± 15.3% in the posterior wall, 19.7 ± 15.3% in the anterior wall, 17.1 ± 15.0% in the right PV antrum, and 12.0 ± 13.2% in the septum wall. LGE was heterogeneously distributed in the LA and was found with the highest frequency in the posterior wall near the inferior left PV antrum by the LGE histogram. A comparison of paroxysmal AF with persistent AF suggests that LGE was more expected in persistent AF compared with paroxysmal AF, particularly with a spread on the posterior and the anterior wall.

CONCLUSIONS LGE in the LA was heterogeneously distributed. LGE was highly distributed in the inferior left PV antrum near the posterior wall side, and spread on the posterior and anterior wall with AF progression. (J Am Coll Cardiol EP 2017;■:■–■) © 2017 by the American College of Cardiology Foundation.

Pulmonary vein (PV) isolation is the cornerstone procedure of atrial fibrillation (AF) ablation, especially for patients with paroxysmal atrial fibrillation (PAF) (1,2). However, in cases of persistent atrial fibrillation (PeAF), structural remodeling in the left atrium (LA) perpetuates AF, and the perpetuation of AF contributes to further developments of remodeling (3–5) (i.e., AF begets AF). Because structural remodeling was already developed and conduction heterogeneity in the LA exists in most cases of PeAF, simple PV isolation is usually not sufficient (3,4). Therefore, remodeled areas in the LA are now the additional target of ablation in patients with PeAF for better outcome by means of LA posterior wall debulking (6) and/or low voltage zone (LVZ) ablation (7–9). Knowing the existence and the spatial distribution of remodeled area in the LA before AF ablation is an increasing concern.

Structural remodeling in the LA can be visualized and quantified using late gadolinium enhancement magnetic resonance imaging (LGE-MRI), and the quantity of LGE in the LA determines the prognosis after AF ablation (10–13). Using image intensity ratio technique, another group also visualized structural remodeling by LGE-MRI (14). However, previous studies have described LGE only as a total percentage of LGE in the LA, and have not yet examined its spatial distribution. In this study, we examined the

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Manuscript received March 24, 2017; revised manuscript received July 3, 2017, accepted July 6, 2017.

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

LA = left atrium

LGE-MRI = late gadolinium enhancement magnetic resonance imaging

LVZ = low voltage zone

PAF = paroxysmal AF

PeAF = persistent AF

PV = pulmonary vein

spatial distribution of LGE by means of a subsegmentation of the LA and by mapping LGE distributions to a statistical shape atlas of the LA for summary and quantitative comparison (15–17).

METHODS

STUDY POPULATION. We retrospectively identified consecutive 160 patients (103 male; mean age 67 ± 11 years) who underwent AF ablation at the University of Utah between September 2009 and June 2011. All patients underwent an interpretable LGE-MRI within 1 month before AF ablation to assess LGE in the LA. Patients were a part of the AF database approved by our institutional review board and were compliant with the Health Insurance Portability and Accountability Act. Patients were classified as PAF or PeAF by the American College of Cardiology, American Heart Association, and European Society of Cardiology guidelines (18).

LGE-MRI ACQUISITION. LGE-MRI was acquired on either a 1.5- or 3.0-T clinical MR scanner (Siemens Medical Solutions, Erlangen, Germany) within 1 month before ablation. The image was acquired about 15 minutes after contrast agent injection (0.1 mmol/kg, Multihance [Bracco Diagnostic Inc., Princeton, New Jersey]) using a 3-dimensional inversion recovery, respiration navigated, electrocardiography-gated, gradient echo pulse sequence. Typical image acquisition parameters included the following: free-breathing using navigator gating, a transverse imaging volume with voxel size = 1.25 × 1.25 × 2.5 mm (reconstructed to 0.625 × 0.625 × 1.25 mm), and an inversion time of 270 to 320 ms. The inversion time value for the LGE-MRI scan was identified using an inversion time scout scan. Repetition time, echo time, and flip angle were optimized to 5.4 ms, 2.3 ms, and 20°, respectively, for the 1.5-T scans, and 3.1 ms, 1.4 ms, and 14°, respectively, for the 3.0-Tesla scans. Electrocardiography gating was used to acquire a small subset of phase encoding views during the diastolic phase of the LA cardiac cycle. The time interval between the R-peak of the electrocardiography and the start of data acquisition was defined using the cine images of the LA. Fat saturation was used to suppress the fat signal. These parameters were previously described (12).

LGE-MRI PROCESSING AND ANALYSIS FOR LGE. MRI scans were evaluated for LGE using the Corview image analysis software (MARREK, Inc., Salt Lake City, Utah). The LA wall was segmented manually from LGE-MRI scans by careful tracing of the LA contour without PVs. Dark blood MRI scans, which can visualize LA endocardium, helped this process to distinguish the LA wall boundaries, especially for the boundary between LA wall and aortic root (Online Figure 1). The PV-LA junction was defined by narrowing diameter of PV insertion area compared with the LA diameter area (Online Figure 2). LGE was distinguished from normal myocardium using an interactive tool for selecting intensity thresholds that correspond with LGE in the LA wall, as previously described (10–13). **Figure 1A** illustrates the process for segmenting the LA wall and determining LGE area. **Figure 1B** shows example images of LGE distributions in the LA (trivial, mild, moderate, and extensive).

SUBSEGMENTATION OF LA. The LA wall was subsegmented into 6 regions: left PV antrum, right PV antrum, posterior wall, septum wall, anterior wall, and left lateral wall. We defined each LA region as follows: (1) the left PV antrum is the LA wall extending 10 mm from the left PV-LA junction, (2) the right PV antrum is the LA wall extending 10 mm from the right PV-LA junction, (3) the posterior wall is the posterior LA extending from the LA floor to the LA roof and bordered by both PV antra, (4) the septum wall is the wall between LA and right atrium, (5) the anterior wall is the anterior part of the LA, and (6) the left lateral wall is the left side of the LA that is not covered by other areas. **Figure 2** shows an example of subsegmentation. After subsegmentation, the LGE area (mm^2) and LGE coverage (%) in each LA subregion were calculated using the Corview software.

SHAPE ATLAS FOR COMPARISON OF LGE ACROSS LA SURFACES. To analyze the spatial distribution of LGE, we summarized LGE appearance data from all 160 LA surfaces by mapping each subject's LGE appearance data to a reference shape taken from an LA atlas. We computed the LA atlas using the ShapeWorks software (Scientific Computing and Imaging Institute, University of Utah, Salt Lake City, Utah), which implements a statistical shape modeling approach described by Cates et al. (15–17). For this analysis, we used MRI scans of the LA surface after excluding PVs from the PV-LA junction. Using the LA image without PVs, the shape modeling approach places 512 landmark points on all LA surfaces, except for the PV ostium, to define a 1-to-1 mapping between surface positions on a different LA surface. Collectively, these mappings form an atlas that allows us to compare LGE appearance at corresponding LA locations across all patients.