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Electrophysiological characteristics of left atrial diverticulum in patients with atrial fibrillation: Electrograms, impedance and clinical implications

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ABSTRACT

Background: Left atrial diverticulum (LAD) is not rare in patients with atrial fibrillation (AF). Recent reports focused on its morphology however data on its electrophysiological characteristics are lacking. Our study aims to investigate the electrogram and impedance features of LAD.
Methods: This study included 24 patients (mean age, 58.5 ± 10.7 years) with LAD undergoing catheter ablation for AF and 24 gender-and-age-matched individuals without LAD as controls. A bipolar LAD electroanatomic map was acquired in sinus rhythm from all study participants. Points were acquired for diverticulum in the LAD group and for corresponding areas in the control group. Electrogram deflections were counted, bipolar voltage and impedance were measured for each point, and average Δimpedance and highest Δimpedance were calculated.
Results: A total of 234 points were collected in the two groups. In the LAD vs. control group, median (Q1, Q3) of electrogram deflections was 6 (5, 7) and 4 (4, 5) ($P < 0.0001$), respectively, voltage was not significantly different (1.58 ± 0.68 mV vs. 1.28 ± 0.65 mV, $P = 0.10$), and average Δimpedance was significantly higher in the LAD group (19.5 ± 9.0 Ω vs 3.9 ± 1.7 Ω, $P < 0.0001$). A cut-off value of 9.5 Ω for Δimpedance predicted LAD with sensitivity, specificity, and positive and negative predictive values of 83.5%, 92.8%, 92.1% and 84.9%, respectively.
Conclusions: Electrogram was more fractionated and impedance was higher at LAD than in corresponding areas without LAD, which might help to differentiate LAD during catheter ablation for AF.

1. Introduction

Atrial fibrillation (AF) is the most common tachyarrhythmia, and catheter ablation is considered a reasonable therapy for paroxysmal AF [1]. Left atrial diverticulum (LAD) is common in AF patients (17% to 41% occurrence) [2–5], with most (74%–80%) [4,5] located at the anterosuperior left atrium in various shapes, namely cystiform, cone-shaped, tubiform and irregular. Examination of an autopsied heart [6] revealed that, despite similar endocardial surface, LAD wall was much thinner than adjacent tissue [3] which might increase tamponade risk for catheter manipulation during mapping and complicate radiofrequency application in LAD. Little is known about the electrophysiological characteristics of LAD, which should be distinguished from those of abnormal left atrial wall without LAD to avoid excessive ablation in LAD. This study therefore investigates the electrogram and impedance features of LAD relative to those of corresponding areas without LAD in AF patients undergoing catheter radiofrequency ablation.

2. Methods

2.1. Patient population

From February 2012 to November 2013, 91 patients with AF underwent multidetector computed tomography (MDCT) pulmonary venography and catheter radiofrequency ablation at our hospital. After excluding patients with congenital and/or valvular heart disease, 24 patients meeting the inclusion criteria (LAD detected by cardiac CT; and presence/restoration of sinus rhythm during ablation) were consecutively assigned to the LAD group while another 24 without LAD, matched with regard to gender and age (±2 years), served as the control group. The study was approved by the institutional review committee of our hospital, and all participants provided informed consent.

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2.2. MDCT protocol

Cardiac CT images were acquired on a 64-slice CT scanner (Discovery CT750 HD, GE Company, USA) using 0.625-mm slice thickness, 350-ms gantry rotation, 120 kV and 500–600 mA. A total of 50–70 mL of non-ionic contrast agent (iopamidol, 370 mg/mL; Bracco Sine Pharmaceutical Corp. Ltd, Shanghai, China) was injected via the antecubital vein followed by 40 mL of saline, both at a flow rate of 5.0 mL/s. Contrast agent tracking was used to synchronize scanning from the thorax entrance to the diaphragm.

Acquired data were transferred to a workstation (AW4.5, GE Company, USA) for image processing, interpretation, and three-dimensional rendering generation. Images were reconstructed with 0.625-mm slice thickness by volume-rendered, multi-planar reformation, and maximum intensity projection reconstructions.

LAD was defined as a protrusion from the heart cavity to outside the left atrial wall plane. For each diverticulum, orifice and cervix width and length were measured. According to a previous study [3], LAD shape was classified as: cystiform, if LAD had a broad orifice and a domelike cecum (i.e., body length/orifice width ratio <3); cone-shaped, if LAD had a broad orifice and looked like a cone; and tubiform, if LAD appeared as a long but small cavity (length/orifice width >3).

2.3. Diverticulum electrogram mapping

The entire process described below was guided by CARTO XP or CARTO 3 (Biosense Webster, Diamond Bar, CA, USA). A bipolar LAD map was acquired in sinus rhythm as carefully as possible during the ablation procedure. If the patient was in atrial fibrillation, cardioversion to sinus rhythm was followed by a waiting period of at least 5 min. A copy of the cardiac computerized tomography taken prior to the procedure was integrated into the electroanatomic mapping system. For both groups, an ablation catheter (Navistar Thermocool, Diamond Bar, CA, Biosense Webster, USA) was used to collect points for electroanatomic mapping.

Due to safety and accuracy of the result, all the ablations were avoided in an area including the diverticulum, of which the diameter was at least 10 mm. If a diverticulum was located close to the pulmonary veins, we left it outside the ablation line. Meanwhile, if the diverticulum was located on the left atrial roof, we tried to move the roof ablation line to a bit anterior or posterior to avoid delivering radiofrequency energy in the diverticulum. We collected points with evaluation of tissue contact based on the stable fluoroscopic motion of the catheter and stable electrogram morphology. Three to five points within a 10-mm-diameter area were acquired for the diverticulum according to its size and shape. For the control group, 3–5 points were also collected in a similar area to that in the LAD group. Number of deflections present in each electrogram was determined by manual counting as previously reported [6]. Electrograms with >5 deflections were defined as fragmented electrograms, while those with ≤5 deflections were considered normal electrograms.

The percentage of fractionated signals was calculated by dividing the number of fractionated signals by the total number of signals at diverticulum in the LAD group or the corresponding area in the control group.

2.4. Voltage mapping

Local voltage of the local electrogram was defined as the amplitude of peak positive-to-peak negative deflections. For each point, bipolar voltage was recorded with the combination of automated algorithms, and manually verified to validate the result. Low voltage was defined by the conventional <0.5 mV cut-off point for the atrium [7].

2.4.1. Impedance mapping

For each point acquired, impedance was recorded during mapping. Concurrently, average impedance of three points around the target area was recorded as the left atrial impedance. Δimpedance was impedance of each point minus the left atrial impedance. The highest Δimpedance of each area was also recorded. Average Δimpedance was calculated by dividing the total Δimpedance by the number of points acquired in the LAD or in the corresponding area in the control group.

2.5. Re-induction or recurrence of atrial fibrillation after catheter ablation

All study participants received high-dose isoproterenol (20–30 μg/min) after ablation to locate additional non-pulmonary vein trigger sites not previously present. Rapid pacing in the coronary sinus was also applied to induce atrial tachycardia arrhythmia.

During the follow-up period, in patients with recurrence of AF or atrial tachycardia, recovery of potentials in pulmonary veins and association with tachycardia were evaluated first; other mechanisms for the tachycardia were sought thereafter.

2.6. Statistical analysis

Continuous data are expressed as mean ± SD or median (25%, 75% interquartile) as appropriate, and categorical variables are presented as percentages. Continuous variables were compared using *t*-test or Mann–Whitney *U* test as appropriate, while Chi-square test or Fisher's exact test were used to compare categorical variables. A two-tailed P value of <0.05 indicated statistical significance. Logistic regression was used to explore the relationship between diverticulum presence and clinical features. Multivariate linear regression was used to confirm the association between electrophysiological characteristics and diverticulum presence.

3. Results

3.1. Patient characteristics

Baseline characteristics of patients are shown in Table 1. There were no significant differences in age, gender, type of atrial fibrillation, left atrial size, left ventricular end diastolic diameter, left ventricular function and complications between the two groups. Logistic regression analysis showed no association between diverticulum occurrence and patient characteristics. In particular, LAD presence was unrelated to left atrial size and type of atrial fibrillation.

3.2. Diverticulum characteristics

A total of 27 LAD were found in 24 of the 91 patients screened. Three patients had multiple diverticula. Twenty LAD (74.1%) were located in the anterosuperior wall, 4 (11.1%) in the septal wall, and only 3 (11.1%) in the inferior wall. LAD presented in three morphologies, including cystiform, cone-shaped and tubiform.

3.3. Diverticulum electrogram characteristics

234 points were collected in the two groups. In the diverticulum group, the most complex signal in diverticulum had 10 deflections (Fig. 1A), the median average deflection of electrograms was 6, and the fractionated signal proportion was 57.1 ± 29.5%. In the control group, the median average deflection of points was 4, and the

Table 1
Patient characteristics in the LAD and control groups.

	LAD group	Control group	P value
Number of patients	24	24	
Age	58.5 ± 10.7	59.2 ± 10.4	0.81
Male gender	17 (70.8%)	17 (70.8%)	1
Type of AF			
Persistent	6 (25%)	9 (37.5%)	0.56
Comorbidities			
Hypertension	12 (50%)	16 (66.7%)	0.53
Diabetes	3 (12.5%)	5 (20.8%)	0.70
Ischemia	6 (25%)	7 (29.2%)	0.98
Echocardiography			
Left atrial size (mm)	35.4 ± 3.81	37.5 ± 5.29	0.14
Left ventricular end diastolic diameter (mm)	46.1 ± 3.0	46.4 ± 5.03	0.79
Left ventricular ejection fraction (%)	62.9 ± 4.68	64.5 ± 7.46	0.32

AF = atrial fibrillation; LAD = left atrial diverticulum.