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Original Article

Wavefront direction and cycle length affect left atrial electrogram amplitude

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ABSTRACT

Background: The relationship between atrial electrogram (EGM) characteristics in atrial fibrillation (AF) and those in sinus rhythm (SR) are generally unknown. The activation rate and direction may affect EGM characteristics. We examined characteristics of left atrial (LA) EGMs obtained during pacing from different sites.

Methods: The study included 10 patients undergoing pulmonary vein isolation for AF. Atrial EGMs were recorded from a 64-pole basket catheter placed in the LA, and bipolar EGM amplitudes from the distal electrode pair (1–2) and proximal electrode pair (6–7) from 8 splines were averaged. The high right atrium (HRA), proximal coronary sinus (CSp), and distal coronary sinus (CSd) were paced at 600 ms and 300 ms.

Results: When the LA voltage at SR was ≥ 1.5 mV, bipolar voltages of the HRA were greater than those of the CSp, which were greater than those of the CSd, regardless of the pacing cycle length. The shorter pacing cycle length resulted in a reduction of the LA EGM voltage at sites of SR voltage ≥ 1.5 mV, but no significant difference was seen at sites where the SR EGM amplitude was between >0.5 and <1.5 mV. No significant differences were seen in intra-basket conduction times between pacing cycle lengths of 600 ms and 300 ms at any pacing site.

Conclusion: The rate and direction-dependent reduction of the amplitude of atrial EGMs may explain, in part, the voltage discordance during SR and AF.

1. Introduction

Although pulmonary vein isolation is a well-established treatment for paroxysmal atrial fibrillation (PAF) [1], the success rate for persistent AF (PerAF) is less than satisfactory [2]. pulmonary vein isolation plus ablation of complex fractionated atrial electrogram (CFAE) sites during AF identified by time domain analysis or high dominant frequency (DF) sites identified by frequency domain analysis during AF has been shown by some studies to improve acute and long-term success rates in patients with PerAF [3,4]. However, the added CFAE ablation has been shown by other studies to be of limited long-term efficacy [5–7]. Recordings of low voltage, fractionated electrograms (EGMs) from the left atrium (LA) during sinus rhythm (SR) in patients with AF [8] has led to individualized atrial substrate modification based on low-voltage areas and a decreased likelihood of AF recurrence, regardless of the AF type [9–12]. Electroanatomical voltage mapping can be used to estimate the degree of myocardial fibrosis in the atria [13]. However, the amplitude of the atrial EGMs may depend on the atrial rhythm and dominant cycle length in cases of AF. Left atrial voltage discordance during tachycardia versus SR has also been described [14,15], but the underlying mechanism is not understood. In previous studies, we showed that most CFAE sites and high DF sites identified during AF do not correspond to high DF sites identified during SR, and we also showed, by spectral analysis of atrial EGMs obtained during SR, that DF and high DF (>70 Hz) are affected by the direction of conduction but not by the pacing rate [16,17]. Herein, we describe a study in which we examined the effects of the direction and rate of activation on LA bipolar EGM voltage.

2. Material and methods

2.1. Study patients

The study included 10 consecutive patients (10 men, mean age: 59.4 ± 9.1 years) scheduled for their first catheter ablation of AF.

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The clinical characteristics of these patients are shown in Table 1. One had PAF (AF lasting less than 7 days), and 9 had PerAF (AF lasting 7 days or more). No patient with cardiomyopathy, valvular heart disease, or congenital heart disease was included in the study. Adequate oral anticoagulation therapy was given for at least 1 month before the ablation procedure, and all antiarrhythmic drugs were discontinued for at least 5 half-lives before the procedure. Transesophageal echocardiography and transthoracic echocardiography were performed upon admission, and the following baseline echocardiographic values were obtained: LA dimension, maximum LA volume by the prolate ellipsoid method, and left ventricular ejection fraction by the Teichholz method. The study protocol was approved by the Institutional Review Board of Nihon University Itabashi Hospital (December 7, 2012; RK-121109-5), and all patients provided written informed consent.

2.2. Electrophysiologic study

Electrophysiologic study was performed in all patients under conscious sedation achieved with dexmedetomidine, propofol, and fentanyl, as described previously [8,9]. After vascular access was obtained, a single transseptal puncture was performed, and intravenous heparin was administered to maintain an activated clotting time of more than 300 s. After 2 long sheaths (1 SL0 sheath and 1 Agilis sheath; St. Jude Medical, Inc., St. Paul, MN, USA) were inserted into the LA via transseptal puncture, the 3-dimensional geometry of the LA and the pulmonary veins (PVs) was reconstructed with the use of an EnSite NavX Classic mapping system (St. Jude Medical, Inc.) and a 64-pole basket catheter (Constellation, EP Technologies/Boston Scientific Corporation, San Jose, CA, USA), which consisted of 8 splines (A–H), each with 8 electrodes 4 mm in length. The basket catheter was deployed in the LA, and the distal end was placed at the left PV antrum (Fig. 1). A basket catheter of adequate size (38 mm with interelectrode spacing of 3 mm, 48 mm with interelectrode spacing of 4 mm, or 60 mm with interelectrode spacing of 5 mm) was chosen for consistent contact with the LA endocardium. We recorded multiple bipolar signals (filter setting: 30–300 Hz) simultaneously during SR. A duo-decapolar catheter (BeeAT, Japan Lifeline Co., Tokyo, Japan) was placed in the coronary sinus (CS) through the right internal jugular vein. If the patient was in AF, SR EGMs were recorded after internal atrial cardioversion was achieved by a single delivery of biphasic energy shocks of 15–20 J. Cardioversion was performed only once, and the electrophysiologic study was conducted after a 30-min waiting period.

Table 1
Characteristics of the study patients.

	$N=10$
Age (years)	59.4 ± 9.1
Male sex	10 (100)
BMI (kg/m^2)	24.9 ± 2.5
Hypertension	3 (30)
Diabetes mellitus	2 (20)
Hyperlipidemia	3 (30)
Heart failure	4 (40)
AF duration (months)	36.0 (6.5–60)
LVEF (%)	63.6 ± 9.7
LAD (mm)	43.5 ± 5.2
LAV (mL)	64.7 ± 23.1

Data are presented as n (%), mean $\pm$ SD, or mean (range).
Abbreviations: AF, atrial fibrillation; BMI, body mass index; LAD, left atrial dimension; LAV, left atrial volume; LVEF, left ventricular ejection fraction.

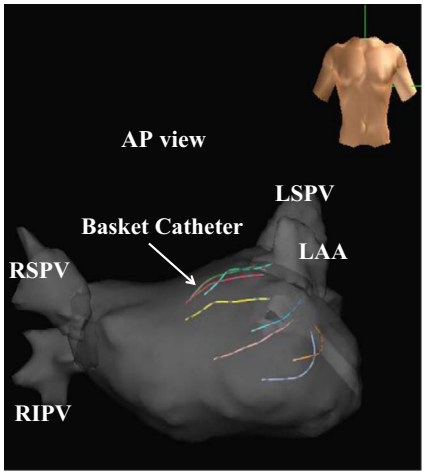

Fig. 1. Position of the basket catheter in the left atrium. Abbreviations: AP, anteroposterior; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.

2.3. Bipolar signal recordings

Because of the limited number of electrodes that can be recorded by the EnSite NavX Classic system, signals from 1 proximal electrode of each spline of the basket catheter were not recorded. Thus, EGMs were recorded from 6 of the 7 bipolar electrode pairs along each spline for a total of 48 bipolar EGMs (6 pairs $\times$ 8 splines) and entered into the analysis. With the basket catheter sitting in a stable position, baseline bipolar signals were recorded from each of the 48 bipoles and stored in the NavX mapping system. DFs were calculated from EGMs obtained during SR and EGMs obtained during pacing from the high right atrium (HRA), proximal CS (CSp), and distal CS (CSd) at pacing rates of 600 ms and 300 ms. The conduction time to each bipolar pair of electrodes on the basket catheter was calculated as the difference observed between the earliest activation and latest activation from the pacing spike. To ensure stability and reliability of the bipolar signals, low voltage (≤ 0.5 mV) bipolar signals recorded during SR

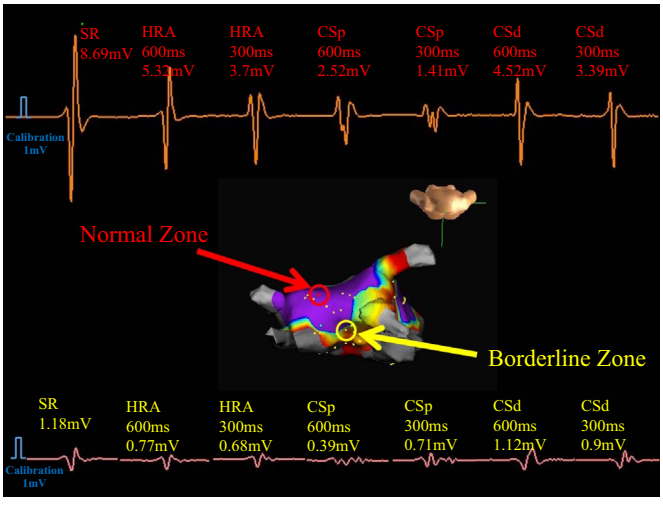

Fig. 2. Representative electrograms in a patient with persistent atrial fibrillation. The upper panel shows a normal electrogram (electrogram amplitude more than 1.5 mV during sinus rhythm). The lower panel shows a borderline electrogram (electrogram amplitude between >0.5 mV and <1.5 mV during sinus rhythm) with changes in bipolar electrograms during sinus rhythm (SR), high right atrium (HRA), proximal coronary sinus (CSp), and distal coronary sinus (CSd) pacing at pacing cycle lengths of 600 and 300 ms. The middle panel shows 3-dimensional distributions of bipolar electrograms where the blue color shows an electrogram amplitude >1.5 mV.

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