Three-Dimensional High-Density Bipolar Contact Mapping of Left Atrial Endocardial Activation During Sinus Rhythm in Patients With Atrial Fibrillation

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Summary

Non-contact array mapping studies have demonstrated the existence of a line of conduction block along the septopulmonary bundle area and the posterior left atrial (LA) roof during sinus rhythm (SR). However, little is known of the global LA activation pattern during SR using a high-density contact bipolar mapping system. High-density contact bipolar isochronal mapping (bipolar mapping sites: 292 [IQR 250-348] points) of the LA was performed during SR with the NavX mapping system in 20 patients with paroxysmal atrial fibrillation (AF) and 11 patients with non-paroxysmal AF. The earliest endocardial breakthrough in the the LA from the right atrium (RA) during SR occurred in the anterosuperior LA (77%) or anterior to the right pulmonary veins (23%), and the breakthrough site did not differ between patients with paroxysmal and non-paroxysmal AF. Regardless of the site of breakthrough, the LA activation pattern was homogeneous, and no line of functional block was observed in any patient. Total LA activation time was significantly longer in non-paroxysmal AF patients than in paroxysmal AF patients (95.1 ± 4.3 ms versus 78.3 ± 3.2 ms, P = 0.0040). Contact-based bipolar LA endocardial activation mapping revealed a homogeneous LA activation pattern during SR, regardless of the between-group difference in activation time and the between-patient difference in sites of earliest LA endocardial breakthrough from the RA. (Int Heart J 2013; 54: 285-288)

Key words: Contact bipolar mapping, Left atrial activation

Pulmonary vein (PV) isolation is a catheter ablation technique performed for paroxysmal atrial fibrillation (AF). However, significant atrial remodeling results in the need for additional ablation strategies, ie, complex fractionated electrogram-based ablation or intra-atrial linear ablation in the left atrium (LA). A better understanding of the LA activation sequence may provide further insight into the mechanisms of AF and be useful in determining LA substrate-based AF ablation strategies. Several groups have described detailed mapping of global LA activation. Initial studies were conducted to record LA epicardial activation by using plaque electrodes during surgery. Recent three-dimensional (3D) non-contact array mapping studies have demonstrated the existence of lines of conduction block along the septopulmonary bundle area or the posterior roof of the LA during sinus rhythm (SR). However, high-density contact bipolar mapping of the LA activation has not been reported. We, therefore, performed global high-density contact bipolar mapping of LA activation during SR in patients with AF.

Methods

Study patients: The study group consisted of 31 consecutive patients (all men, aged 55.5 ± 12.8 years) who underwent catheter ablation of AF (Table), 20 with paroxysmal AF (AF lasting less than 7 days) and 11 with non-paroxysmal AF (AF lasting more than 7 days). Thirteen patients had hypertension, and 4 had diabetes. Two patients had significantly impaired LV systolic function; the remaining 12 patients had no structural heart disease. No patients had severe valvular heart disease, cardiomyopathy, or congenital heart disease. 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 baseline echocardiographic values were recorded. The study was approved by the Institutional Review Board of Nihon University Itabashi Hospital, and all patients provided written informed consent for their participation.

Electrophysiologic study: Details of the electrophysiologic study and ablation strategy have been described previously. In brief, electrophysiologic study was performed under con-
Between-group differences were analyzed by Student’s t test or the Mann-Whitney U test. Fisher’s exact probability test was used to compare the distribution of dichotomous variables between patients with paroxysmal AF and non-paroxysmal AF. A P < 0.05 was considered to be statistically significant. All statistical analyses were performed with JMP 8 software (SAS Institute, Cary, NC, USA).

### RESULTS

**Clinical characteristics:** The clinical characteristics of the patients are summarized in the Table. Body mass index was significantly greater in the non-paroxysmal AF patients than in the paroxysmal AF patients (27.0 ± 1.4 kg/m² versus 22.3 ± 1.0 kg/m², P = 0.0144). In addition, the duration of AF was significantly longer (71 [IQR 70-100] months versus 28 [IQR 10-62] months, P = 0.0107), hypertension was significantly more prevalent (82% versus 20%, P = 0.0017), and LA diameter was significantly greater (45.9 ± 1.9 mm versus 38.6 ± 1.4 mm, P = 0.0044). Other variables did not differ statistically between the two groups.

**LA activation configuration of the 3D high-density contact bipolar LA mapping:** Over 292 [IQR 250-348] data points were acquired per patient for creation of the LA isochronal maps. The earliest endocardial breakthrough from the RA was observed at the anterosuperior LA in 24 patients (77% of the total patients) (Figure 1) and anterior to the right PVs in the remaining 7 patients (23%) (Figure 2). There was no difference in the prevalence of breakthrough at the anterosuperior LA between the two groups of patients (75% versus 64%, P = 0.6828). In all patients, regardless of the site of breakthrough, the propagation wavefront split into two wavefronts: one wavefront traveled to the LA septum and then to the posterior LA wall in a superomedial or medial to lateral direction, and the other traveled from the anterior LA roof to the mitral annulus. These two wavefronts ultimately collided at the lateral or inferolateral portion of the mitral isthmus (Figures 1 and 2). No line of conduction block as manifested by the presence of double potentials was observed in the LA. Total LA activation time was significantly longer in the patients with non-paroxysmal AF than in those with paroxysmal AF (95.1 ± 4.3 ms versus 78.3 ± 3.2 ms, P = 0.0040).

### DISCUSSION

In our study patients, global LA endocardial activation as determined by 3D high-density bipolar mapping was homogeneous, and there was no line of conduction block in the LA body during SR. LA activation time was longer in the patients with non-paroxysmal AF than in those with paroxysmal AF patients, but no difference was found in the LA activation pattern between the two groups.

| Table. Patient Characteristics and Baseline Echocardiographic Values in All Patients and per Group (Paroxysmal AF and Non-Paroxysmal AF) |
|-----------------|-----------------|-----------------|-----------------|--------|
| Age (years) | 55.5 ± 12.8 | 53.0 ± 2.8 | 59.9 ± 3.8 | 0.1543 |
| BMI (kg/m²) | 24.0 ± 4.0 | 22.3 ± 1.0 | 27.0 ± 1.4 | 0.0144 |
| AF duration (months) | 45 (18-72) | 28 (10-62) | 71 (70-101) | 0.0107 |
| Hypertension | 13 (42%) | 4 (20%) | 9 (82%) | 0.0017 |
| Diabetes | 4 (13%) | 1 (5%) | 3 (27%) | 0.1154 |
| CHF | 2 (6%) | 0 (0%) | 2 (18%) | 0.1183 |
| LAD (mm) | 41.2 ± 7.2 | 38.6 ± 1.4 | 45.9 ± 1.9 | 0.0044 |
| LVEF (%) | 66.2 ± 10.8 | 63.9 ± 2.8 | 71.6 ± 4.3 | 0.1493 |

Values shown are mean ± SD, median (25th percentile, 75th percentile), or number (%). CHF indicates congestive heart failure; LAD, left atrial diameter; and LVEF, left ventricular ejection fraction. *Paroxysmal AF non-paroxysmal AF.
A previous study of RA and LA activation patterns during SR recorded from multipolar plaque electrodes revealed that activation wavefronts propagated across the RA to the LA at the posterior surface beneath the right lower PV or through Bachmann’s bundle.8 Recent studies based on non-contact mapping reported the earliest LA activation site to be most commonly located at the posteroanterior wall adjacent to the right PVs and anterosuperior LA.5,10 The findings of these studies were similar to the findings of our high-density contact bipolar mapping study reported herein. Although variation in the earliest LA activation sites was shown by the different mapping techniques, in all patients, Bachmann’s bundle was shown to act as an important anatomical structure for LA activation from the RA. However, all studies of global LA activation that made use of non-contact mapping revealed a line of conduction block along the septopulmonary bundle coincides with the junction between a band of longitudinal myocardial fibers that lie adjacent to the septum and right PVs and a band of circumferential fibers that run perpendicularly toward the lateral LA.6,13 These studies suggested that, because of anisotropic muscle fiber orientation or myocardial fibrosis, the septopulmonary bundle can function as an anatomical obstacle to wavefront propagation, resulting in conduction delay or block.5,10 Markides, et al reported a line of complete conduction block along the septopulmonary bundle fibers.9 Rha, et al reported that anatomical structures showing frequent wavebreak and slow conduction during AF were located most often at the septopulmonary bundle (86.5%) or posterior LA roof between the left superior PV and right superior PV (54.1%), suggesting that these anatomical structures play an important role in maintenance of AF.11 In contrast, our present high-density contact bipolar LA mapping study showed the LA activation wavefronts to be homogeneous without a line of conduction block in the LA body. In a previous CARTO-based 3D contact bipolar mapping study of LA activation, no conduction block was identified at the posterior LA.14 The different results produced by the contact versus non-contact mapping systems may be due to the difference in acquisition of electrograms, ie, contact-based bipolar electrograms versus non-contact-based virtual unipolar electrograms. The accuracy of virtual unipolar electrogram information depends on the distance from the balloon array to the target endocardial surface.15,16 The absolute timing accuracy of noncontact electrograms has been reported to decrease at sites located > 4 cm from the balloon center. When the noncontact mapping catheter is placed toward the LAA or left superior PV, an area surrounding the right PVs is contralateral to the target recording area. Inadequate detection of the activation around the right PVs may distort the global LA activation sequence, leading to the interpretation of conduction block in this area. In fact, most studies based on non-contact systems have shown conduction block or delay around the antra of the right PVs. In contrast, activation determined by means of contact bipolar electrograms is more accurate and therefore more reliable than that determined by virtual unipolar electrograms. LA activation time was significantly longer in our patients with paroxysmal AF than in those with non-paroxysmal AF. However, the LA activation pattern did not differ between the two groups. This finding suggests that conduction block at the septopulmonary bundle may not be present even in cases of non-paroxysmal AF with extensive LA conduction disturbance.

**Limitations:** Our study was limited by the fact that we did not compare the LA activation sequence between contact bipolar-
based mapping and non-contact mapping. Prior studies based on non-contact mapping showed conduction block in the posterior LA at the septopulmonary bundle in a majority of AF patients. However, upon high-density contact bipolar-based mapping, we could identify neither conduction block nor conduction delay at the posterior LA. In addition, our study patients might have less pathological/electrical remodeling because we did not include the patients with long-lasting AF accompanied by advanced mitral valve diseases or severe structural heart disease. Therefore, our study was limited to the relatively intact LA. Finally, we did not evaluate the effect of the pacing site and pacing cycle length on global LA activation because we focused only on the existence of fixed conduction block at the septopulmonary bundle during SR in patients with AF. Further studies are needed to clarify the role of the septopulmonary bundle in the initiation and maintenance of AF.

**Conclusions:** Contact-based bipolar LA endocardial mapping revealed homogeneous activation of the LA during SR, regardless of a between-group difference in activation time and between-patient difference in the site of earliest LA endocardial breakthrough from the RA.

**References**