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Original Article

Usefulness of filtered unipolar electrogram morphology for evaluating transmurality of ablated lesions during pulmonary vein isolation

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ABSTRACT

Background: Although alteration of the amplitude and morphology of bipolar electrograms is used widely as a guide of the ablation effect, there is little information concerning unipolar electrograms. The amplitude and morphology of filtered bipolar (BP) and filtered unipolar (UP) electrograms were compared during pulmonary vein isolation in patients with atrial fibrillation.

Methods: BP (30–250 Hz) and UP (30–100 Hz) signals from the ablation catheter were recorded before and after each ablation point at the pulmonary vein antrum in 6 patients with atrial fibrillation.

Results: In the electrogram group with low-voltage amplitude in BP electrograms before ablation (<0.5 mV), the reduction in amplitude after ablation was significantly greater in the UP than in the BP electrograms, whereas the reduction was similar between the two recording methods in the electrogram group with high-voltage amplitude in BP electrograms (≥ 0.5 mV). Furthermore, the S wave in the UP electrograms disappeared at the sites of no pace capture after ablation, whereas no characteristic morphologic changes were observed in the BP electrograms.

Conclusion: Filtered UP electrograms may be useful in assessing the effectiveness of lesion formation.

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1. Introduction

Extensive encircling ipsilateral pulmonary vein (PV) isolation (EEPVI) has been validated as a curative therapy for paroxysmal and persistent atrial fibrillation (AF) [1–3]. Complete conduction block requires a contiguous line of ablation lesions [4]. Although previous studies have shown that power titration guided by amplitude reduction in the local atrial electrogram succeeds in avoiding complications [5–7], whether the amplitude reduction observed in local bipolar (BP) and unipolar (UP) electrograms recorded after an ablation can reliably predict transmural lesion formation is controversial [5–8]. The effect of different catheter orientations relative to the endocardial surface, the direction of the wavefront on the BP electrogram recorded from transmural and non-transmural lesions, and a comparison of the UP and BP electrograms for the identification of transmural lesion formation at different catheter orientations were reported in an animal model [9]. However, it is difficult to monitor unfiltered UP electrograms during the application of radiofrequency (RF) energy because of electrogram drift. Therefore, we compared filtered UP electrograms and filtered BP electrograms for their usefulness in guiding the creation of transmural atrial lesions during the application of RF energy in EEPVI.

2. Material and methods

2.1. Patients

Six patients with drug-refractory paroxysmal AF comprised the study group. The Institutional Review Board of Nihon University Itabashi Hospital approved this study on April 15, 2012 (IRB number: 8). Written informed consent was obtained from each participant.

2.2. Mapping and RF catheter ablation

BARD LabSystemTM PRO (Murray Hill, NJ, USA) was used for intracardiac electrogram recordings and NavX^{TM} Velocity System (St. Jude Medical, St. Paul, MN, USA) was used for creating a three-dimensional geometric map. Left and right EEPVIs were performed

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antrally for 30 s at each site on the atrial side around the circular mapping catheters until the occurrence of entrance block using a 3.5 mm irrigated tip catheter (ThermoCool; Biosense Webster, Inc., Diamond Bar, CA, USA), which is defined as the loss of all ipsilateral PV potentials, as well as the loss of dormant PV conduction by the administration of 30 mg of ATP. After each ablation, UP pacing (output, 10 mA; pulse width, 2 ms) was performed from the ablation catheter. Since a previous animal study demonstrated that the pacing thresholds increased significantly more at sites with transmural necrosis (unipolar: increase by $378 \pm 103\%$ vs. $207 \pm 93\%$; non-transmural, $P < 0.001$) [10], we arbitrarily defined loss of unipolar pacing capture of 10 mA, 2 ms as transmural lesion formation because pacing threshold before ablation is usually < 2 mA/2 ms; ablation was repeated until the absence of left atrial (LA) capture was achieved [11].

2.3. Post-ablation electrogram characteristics

The filter settings were 30–250 Hz for the BP electrograms and 30–100 Hz for the UP electrograms. The proximal pole of a pentapolar catheter placed in the aorta was used as the indifferent cathodal reference for the UP electrode. BP and UP electrograms that were recorded from a total of 140 ablated points from 6 patients were assessed before and after each ablation, as well as after the absence of LA capture was achieved (Fig. 1A, B). The filtered BP and UP electrograms were analyzed for peak-to-peak amplitude, which is defined as the voltage difference between the highest and lowest deflections, as well as the qualitative analysis of the development of an R or rr′ morphology (change from RSr′ or rSr′ to R or rr′) visually in the UP electrograms.

2.4. Statistical analysis

Continuous variables are presented as mean ± standard deviation, and the Wilcoxon signed-rank test was used to analyze differences in these variables. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Effect of ablation on electrogram voltage

We analyzed 5–6 electrograms per pulmonary vein, and a total of 140 electrograms were analyzed. When baseline pre-ablation BP and UP electrogram amplitudes were compared with the post-ablation electrogram amplitudes in the absence of LA capture, the voltages of the BP and UP electrograms decreased from 0.51 ± 0.33 mV to 0.28 ± 0.19 mV ($P=0.002$) and from 0.54 ± 0.33 mV to 0.31 ± 0.19 mV ($P < 0.01$), respectively. We then classified the pre-ablation BP electrogram voltages into high ($\geq$ 0.5 mV, $n=75$ electrograms) and low BP voltage groups ($<$ 0.5 mV, $n=65$ electrograms). In the high BP voltage group, the post-ablation reduction in voltage was similar between the BP and UP electrograms (0.59 ± 1.2 mV vs. 0.39 ± 0.27 mV, $P=0.2565$). In the low BP voltage group, however, the post-ablation reduction in voltage was significantly greater in the UP compared to the BP electrograms (0.15 ± 0.12 mV vs. 0.10 ± 0.12 mV, $P=0.0063$).

3.2. Effect of ablation on UP electrogram morphology

Local filtered UP electrograms before ablation showed an rSr′ or RSr′ pattern. At the site where the LA capture remained present, filtered UP electrograms showed an rsr′ or Rsr′ pattern. However, where LA capture was absent, UP electrograms showed an R or rr′ pattern (Fig. 2A, B and Table 1). In contrast, no characteristic morphologic changes were observed in BP electrograms.

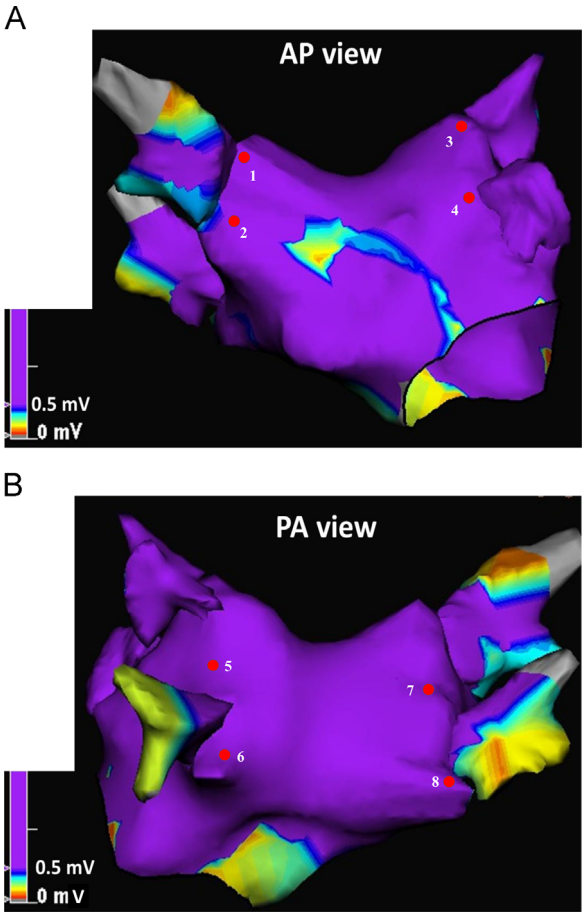

Fig. 1. Three-dimensional mapping images of the left atrium showing representative recording sites (indicated by red dots) of bipolar and filtered unipolar electrograms. The recordings were made at 4 points on the anterior (A) and 4 points on the posterior (B) pulmonary vein antra. AP: anteroposterior; PA: posteroanterior.

4. Discussion

4.1. Main findings

Filtered BP and UP LA electrogram voltages recorded from the ablation catheter decreased significantly after ablation at the sites of no pace capture, and only the UP electrograms showed a significant reduction in voltage after ablation at the sites where the pre-ablation BP voltage was < 0.5 mV. Furthermore, filtered UP electrogram morphology showed an rsr′ or Rsr′ pattern at the pace-capture sites, which changed to an R or rr′ pattern in the absence of LA capture. Otomo et al. [9] showed that, in porcine atria, transmural atrial ablation lesions were associated with loss of the terminal S wave in UP electrograms. Michowitz et al. [12] reported that in UP electrograms recorded in humans from a circumferential mapping catheter after achievement of entrance block, a UP terminal S wave of > 0.2 mV was associated with post-ablation capture with an overall accuracy of 58%.

4.2. Clinical implications

Otomo et al. [9] used filter settings for UP electrogram recordings of 0.5 Hz and 100 Hz, and Michowitz et al. [12] used

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