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Original Article

Evaluation of the characteristics of rotational activation at high-dominant frequency and complex fractionated atrial electrogram sites during atrial fibrillation

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ABSTRACT

Background: High-dominant frequency (DF) and continuous complex fractionated atrial electrogram (CFAE) sites as surrogates for localized sources maintaining atrial fibrillation (AF) are potential AF ablation targets. This study aimed to evaluate the characteristics of a rotational activation at high-DF and continuous CFAE sites in AF patients.

Methods: Thirty-two consecutive AF patients (5 paroxysmal and 27 non-paroxysmal) underwent ablation using the NavX system. When AF continued after circumferential pulmonary vein isolation (PVI), high-DF sites of ≥ 8 Hz and continuous CFAE sites (fractionated intervals ≤ 50 ms) in the left (LA) and right (RA) atria were recorded using a high-density 20-pole circular mapping catheter for 5 s and ablated.

Results: The atrial electrogram characteristics during AF were assessed. A total of 2383 AF beats from 89 high-DF and 19 continuous CFAE sites were investigated. A rotational activation of high-DF and continuous CFAE sites was also observed at 4% and 3% of LA, and 4% and 4% of RA sites, respectively. However, rotational activation was identified in 29 (91%) of 32 patients (mean 3.0 ± 2.6 beats per patient, 80% in the LA). Procedural endpoints were achieved in 26 (81%) of 32 patients: AF termination ($n=2$) and AF cycle length slowing of $> 10\%$ ($n=26$).

Conclusions: Rotational activation could be identified in high-DF and continuous CFAE sites during AF, but the documentation was limited. Therefore, only limited effects of rotational activation ablation at high-DF and/or continuous CFAE sites following PVI could be concluded.

1. Introduction

Pulmonary vein isolation (PVI) has become an accepted treatment for atrial fibrillation (AF) [1]. The efficacy of PVI is sometimes insufficient, and atrial substrate modification of target specific AF signals indicating the substrate responsible for AF perpetuation has been proposed [2,3]. Complex fractionated atrial electrograms (CFAEs), which are electrograms that demonstrate continuous fractionation and very short cycle lengths during AF, may represent the substrate of AF [2,3]. In addition, atrial sites that represent local electrograms with high-dominant frequencies (DFs) may be associated with AF maintenance [4–6]. We reported that a combined high-DF site and continuous CFAE site (fractionated intervals ≤ 50 ms) ablation for the atrial substrate following PVI was effective in both paroxysmal and persistent AF [7]. High-DF and continuous CFAE sites as surrogates for localized sources maintaining AF were potential AF ablation targets [7]. On the other hand, localized electrical sources (rotor and focal impulse) have been reported to be prevalent sustaining mechanisms of human AF using a specific computational mapping device [8]. The patients who underwent a focal impulse and rotor modulation (FIRM)-guided ablation maintained a higher freedom from AF. However, AF rotors did not exhibit consistent or characteristic fractionated electrogram features [9,10]. In another report, FIRM-identified rotor sites did not exhibit any quantitative atrial electrogram characteristics and rotor ablation resulted in AF termination or organization in a minority of the patients [11]. Therefore, this study aimed to evaluate the atrial characteristic electrogram features at high-DF and continuous CFAE sites during AF using a high-density 20-pole circular mapping catheter.

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2. Materials and methods

2.1. Study population

A total of 32 consecutive AF patients (57 ± 12 years) between April 2013 and December 2013 were examined in a prospective review. Paroxysmal AF was defined as AF lasting < 7 days, persistent AF as AF lasting ≥ 7 days but < 1 year, and long-standing AF as continuous AF lasting ≥ 1 year [12]. All anti-arrhythmic drugs were discontinued for at least 5 half-lives, and no patients received any oral amiodarone therapy before the electrophysiological study. The protocol was approved by the institution research and ethics committee of Gunma Prefectural Cardiovascular Center on June 15, 2012. All patients provided written informed consent.

2.2. Electrophysiological study

The NavX system (NavX with CFE software, St. Jude Medical Inc., St. Paul, MN, USA) was used for catheter ablation. A 5-F deflectable catheter was inserted into the coronary sinus (CS) via the right femoral vein. The trans-septal procedure was performed using fluoroscopic landmarks, and three 8-F SL0 sheaths (St. Jude Medical Inc.) were advanced into the left atrium (LA). After the trans-septal procedure, a single bolus of 5000 U of heparin was administered. A continuous infusion with heparinized saline was administered to maintain an activated clotting time of 300–350 s. The 3-dimensional biatrial geometry was created on the NavX system, and sequential contact mapping was performed using a 7-F decapolar circular catheter (Lasso, Biosense-Webster, Inc., Diamond Bar, CA, USA). The points in each region were similar in number and nearly equally distributed. The mapping was performed during AF.

2.3. Fractionation and frequency analysis

The mapping parameter (CFAE-mean) was defined as an interval-analysis algorithm that measured the average index of the fractionation. Recordings at each site were 5 s in length [4]. A continuous CFAE was defined by an average fractionated interval of ≤ 50 ms, indicating a high degree of temporal stability of the fractionated electrograms maintaining AF [4]. The fast Fourier transform method has been described previously [4]. Signals were truncated to 3.41 s at sampling rates of 1200 Hz, providing 4096 points for analysis (resolution 0.29 Hz). The signals were rectified and processed by a Hanning window function and filtered from 2 to 100 Hz. The DF point was determined as the frequency associated with the maximum peak power of the spectrum. Only DF points with a fast Fourier transform ratio of > 0.2 were included [5,6]. The high-DF sites were defined as DFs of ≥ 8 Hz [6].

2.4. Atrial electrogram characteristics analysis

When AF continued after the circumferential PVI, high-DF sites and continuous CFAE sites in the LA and right atrium (RA) were recorded using a high-density 20-pole mapping circular catheter (St. Jude Medical Inc.) for 5 s and ablated. The roving acquisition interval was defined as the mean cycle length of 10 beats using a regular potential from the CS. The creation of a manual propagation map for 5 s during AF was performed and assessed retrospectively. A total of 2383 maps were created. The activation pattern at high-DF and continuous CFAE sites in the LA and RA was classified into the following 6 patterns: rotation, pivot, slow conducting channels, focal, passive, and wave collision (Fig. 1). A rotation was visually defined as a rotational activation of ≥ 1 rotation with a serial electrogram encompassing the time window. A pivot was defined as the core of the rotational activation. All measurements were performed by 2 independent observers

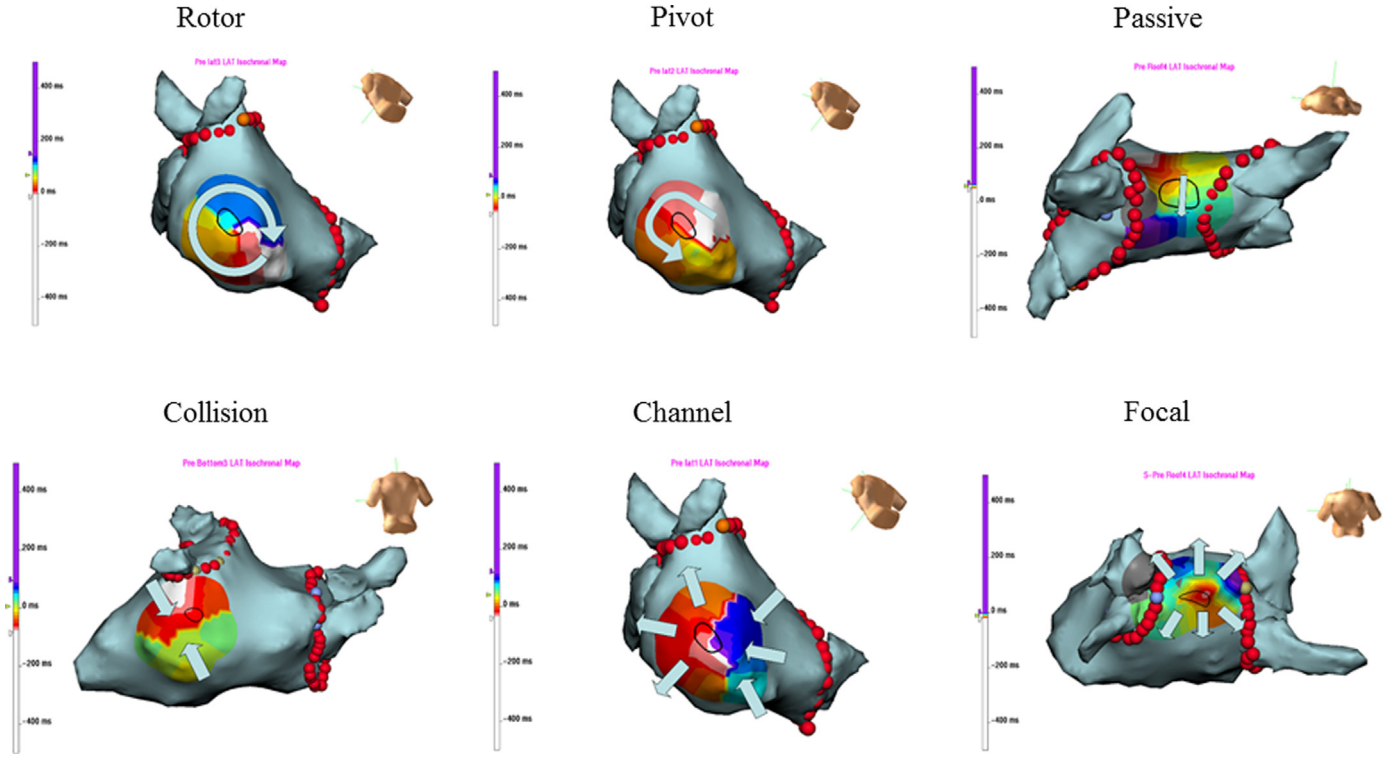

Fig. 1. Representative activation pattern in atrial fibrillation. The activation pattern of 6 typical examples at high-dominant frequency and continuous complex fractionated atrial electrogram sites in atrial fibrillation are shown.