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Original Article

Localized rotors and focal impulse sources within the left atrium in human atrial fibrillation: A phase analysis of contact basket catheter electrograms



Naoko Sasaki, MD^a, Yasuo Okumura, MD, PhD^{a,*}, Ichiro Watanabe, MD, PhD^a, Andrew Madry, PhD^b, Yuki Hamano, BE^b, Mizuki Nikaido, BE^c, Rikitake Kogawa, MD^a, Koichi Nagashima, MD, PhD^a, Keiko Takahashi, MD^a, Kazuki Iso, MD^a, Kimie Ohkubo, MD, PhD^a, Toshiko Nakai, MD, PhD^a, Atsushi Hirayama, MD, PhD^a

^a Division of Cardiology, Department of Medicine, Nihon University School of Medicine, Tokyo, Japan

^b Cuoretech Pty. Ltd., Sydney, Australia

^c Nihon Kohden Corporation, Tokyo, Japan

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ABSTRACT

Background: Consistent detection of rotor(s) and/or focal impulse(s) of atrial fibrillation can using a 64-pole basket catheter remain unclear.

Methods and results: Intracardiac left atrial electrograms were recorded, prior to ablation, in 20 patients with atrial fibrillation. Unipolar electrograms, filtered at 0.1–300 Hz, were recorded and exported for an offline phase analysis. From the cohort, 8 of the 20 patients had analyzable data. Localized rotors were identified in 3 of these patients, with focal impulses detected in 4 patients.

Conclusion: Localized rotors and focal impulses can be identified on phase maps of atrial fibrillation in a small number of patients.

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1. Background

The existence of localized rotors and focal impulses has been reported in human atrial fibrillation (AF) [1]. Phase mapping has been used to characterize the spatiotemporal variability of electrical activities, thereby providing insight into the mechanisms of AF [1,2]. Although the existence of a rotor, along with fibrillatory conduction, has been reported to contribute to maintenance of AF [3], the prevalence and specific role of stable rotors and/or focal impulses in human AF remain unclear. Therefore, we investigated whether rotors and focal impulses can be identified in human AF by analyzing intracardiac electrograms recorded from a multi-electrode catheter.

2. Methods

2.1. Study patients

This study included 20 consecutive patients undergoing initial catheter ablation for drug-refractory AF: 9 for paroxysmal AF

(spontaneous termination within 7 days), and 11 for persistent AF (AF lasting more than 7 days). 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 for participation in the study, which was conducted under ethics committee approval. All antiarrhythmic drugs were discontinued for at least 5 half-lives before ablation, and all patients underwent multidetector-row computed tomography for construction of 3-dimensional maps of the left atrium (LA) (NavX system; St. Jude Medical, Inc., St. Paul, MN, USA).

2.2. Electrophysiological study and unipole signal recordings

Electrophysiological study was performed with patients under conscious sedation that was achieved with propofol and fentanyl [4,5]. After 2 long sheaths (1 SLO sheath and 1 Agilis sheath; St. Jude Medical, Inc.) were inserted into the LA via transseptal puncture; the 3-dimensional geometry of the LA and the 4 pulmonary veins (PVs) were reconstructed by using the EnSite NavX navigation system (v8.0; St. Jude Medical, Inc.), and a 20-pole circular mapping catheter with 1.5-mm interelectrode spacing (Livewire Spiral HP catheter, St. Jude Medical, Inc.). Thereafter, a 64-pole basket catheter (BC), consisting of 8 splines with 8 electrodes each (Boston Scientific, Natick, MA, USA), was placed in the

* Correspondence to: 30-1 Ohayaguchi-kamicho, Itabashi-ku, Tokyo 173-8610, Japan. Tel.: +81 3 3972 2413; fax: +81 3 3972 1098.

E-mail address: yasuwo128@yahoo.co.jp (Y. Okumura).

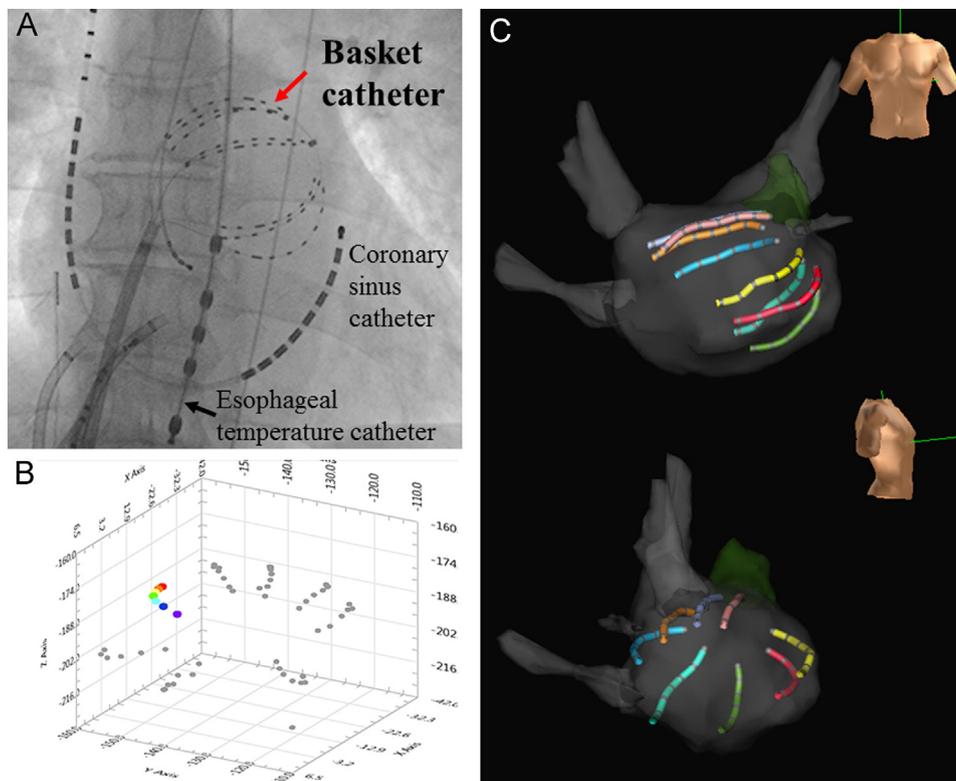


Fig. 1. Data acquisition from a basket catheter (BC). (A) Fluoroscopic image (anteroposterior view) of the BC (red arrow). The catheter is placed in the posterolateral left atrium (LA). (B) Panoramic diagram of the BC in the LA chamber, as depicted by the CEPAS. The proximal electrodes are indicated by red dots and the distal electrodes by purple dots. (C) Three-dimensional electroanatomic shell of the LA showing the BC. Anteroposterior view (upper image) and right lateral view (lower image). The distal electrodes are seen on the right side, and the proximal electrodes on the left side, of the upper image.

LA and labeled on the EnSite NavX system, and simultaneous 60-s unipolar signals were recorded with a filter setting of 0.1–300 Hz. The BC was deployed in the LA, with the distal end placed at the superior left pulmonary vein antrum (Fig. 1). A BC of adequate size (38 mm, 48 mm, or 60 mm with an interelectrode spacing of 3 mm, 4 mm, or 5 mm, respectively) was selected for consistent contact with the LA endocardium. If the patient was in sinus rhythm, AF was induced via rapid atrial pacing from the coronary sinus ostium. Each 10-s data segment was exported for offline phase mapping analysis, which was performed with CEPAS software (Cuoretech Pty. Ltd., Sydney, Australia).

2.3. Phase mapping analysis

CEPAS™ incorporates user-defined characteristics to identify electrogram activations on each unipole of the mapping catheter. These characteristics include (i) baseline noise threshold, (ii) electrogram width criterion, to avoid detection of broad far-field activation, (iii) electrogram slope, and (iv) electrogram refractory periods, to avoid multiple detections within the same activation. For analysis, the noise threshold was set at 0.1 mV, width criterion at 10 ms, and the refractory period at 50 ms. Activation timing was then used to compute the phase [6]. Prior to activation detection and phase mapping, the signals were filtered, using the CEPAS system, with a 50 Hz alternating current removal filter (only if required), low pass filter with a cutoff frequency of 100 Hz to remove high frequency noise, and a wavelet filter as a wandering baseline removal filter. Any ventricular activation picked up, typically on the splines closest to the mitral annulus, was removed using a V wave removal algorithm. The activation detection algorithm automatically detects

activations for all channels (Fig. 2). If the automatic detection algorithm did not work accurately, based on an expert user's opinion, either by missing activations or by falsely including activations, manual adjustments were possible to add, remove, or adjust the location of activations on individual channels. The phase map was oriented to give a 2-dimensional representation of the LA.

2.4. Fast Fourier transform (FFT) analysis

Frequency domain analysis with FFT, to estimate the power spectra of the signals [4,5], was performed simultaneously with phase mapping [7]. For this analysis, the exported signals were filtered using the same filters as used for phase mapping. The atrial fibrillatory signals were full wave rectified, and the FFT window was set to flat-top. The spectrum was computed by means of the FFT. The dominant frequency (DF) was defined as the frequency with the maximum power in the frequency range of 3–15 Hz [8]. The regularity index, defined as the ratio of the area under the curve of the spectrum, within the 0.75-Hz band around the DF, to the area under the spectrum curve over the whole 3–15-Hz band, was computed simultaneously to quantify the sharpness of the dominant peak [9]. The rotor was defined as a stable rotating pattern of 360° observed on the phase map.

3. Results

Patient mean age was 54 ± 12 years, and all were men. The median AF duration was 60 (17–109) months, and mean

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