

Effect of spatial resolution and filtering on mapping cardiac fibrillation

Benjamin King, MBBS,* Andreu Porta-Sánchez, MD,[†] Stéphane Massé, MASc,[†]
Nima Zamiri, MD, MSc,[†] Krishanand Balasundaram, MASc,[†] Marjan Kusha, MEng,[†]
Nicholas Jackson, MBBS,[†] Shouvik Halder, MRCP, MD (Res),[†] Karthikeyan Umapathy, PhD,[†]
Kumaraswamy Nanthakumar, MD[†]

*From the *University of Western Australia, Perth, Australia, and [†]University Health Network, Toronto, Ontario, Canada.*

BACKGROUND Endocardial mapping tools use variable interelectrode resolution, whereas body surface mapping tools use narrow bandpass filtering (BPF) to map fibrillatory mechanisms established by high-resolution optical imaging.

OBJECTIVE The purpose of this study was to study the effect of resolution and BPF on the underlying mechanism being mapped.

METHODS Hearts from 14 healthy New Zealand white rabbits were Langendorff perfused. We studied the effect of spatial resolution and BPF on the location and characterization of rotors by comparing phase singularities detected by high-resolution unfiltered optical maps and of fibrillating myocardium with decimated and filtered maps with simulated electrode spacing of 2, 5, and 8 mm.

RESULTS As we decimated the maps with 2-mm, 5-mm, and 8-mm interelectrode spacing, the mean ($\pm$ SD) number of rotors detected decreased from 10.2 ± 9.6 , 1.6 ± 3.2 , and 0.2 ± 0.5 , respectively. Lowering the resolution led to synthesized pseudo-rotors that may

be inappropriately identified. Applying a BPF led to fewer mean phase singularities detected (248 ± 207 vs 333 ± 130 ; $P < .01$), giving the appearance of pseudo-spatial stability measured as translation index (with BPF 3.6 ± 0.4 mm vs 4.0 ± 0.5 mm without BPF; $P < .01$) and pseudo-temporal stability with longer duration (70.0 ± 17.6 ms in BPF maps vs 44.1 ± 6.6 ms in unfiltered maps; $P < .001$) than true underlying fibrillating myocardium mapped.

CONCLUSION Electrode resolution and BPF of electrograms can result in distortion of the underlying electrophysiology of fibrillation. Newer mapping techniques need to demonstrate sensitivity analysis to quantify the degree of distortion before clinical use to avoid inaccurate electrophysiologic interpretation.

KEYWORDS Atrial fibrillation; Ventricular fibrillation; Rotor; Optical mapping; Multielectrode mapping; Electrode resolution; Signal filters

(Heart Rhythm 2017;0:1–8) © 2017 Heart Rhythm Society. All rights reserved.

Introduction

Mechanisms of cardiac fibrillation and their relevance to the maintenance of atrial fibrillation (AF) and ventricular fibrillation have become pertinent to designing therapeutic strategies.¹ Two recent commercial strategies for treating AF^{2,3} center around localizing focal sources within the myocardium with characteristic wavefront patterns and organizational centers termed rotors, which may be critical to the maintenance of fibrillation.^{4,5} Subsequently, these sites may be considered targets for therapeutic ablation.^{6–8} However, a highly variable success rate has been reported with AF ablation strategies targeting rotors from the

endocardium⁹ and human recordings have shown that the number of electrodes used and its distance is critical to the number of rotors recorded during AF.¹⁰ Both commercial strategies have been clinically deployed without sensitivity analysis with regard to resolution and filtering parameters.

Optical mapping of voltage in which mechanisms of fibrillation were elucidated has a pixel resolution equivalent to electrode spacing of approximately 0.16 mm.^{11,12} Open chest large mammal/surgical models using high electrode resolution (2- to 5-mm spacing) on electrical plaques^{13,14} suggest small diameter and variable rotors^{4,15,16} or lack of rotational activity.¹⁷ In contrast, rotors seen in one of the commercial clinical mapping systems with a resolution > 4 mm have been large, stable, and longstanding when mapped using a multielectrode basket catheter.⁵ Whether a multi-electrode basket catheter is deployed fully and uniformly can vary the electrode spacing between 4 and 12 mm. Therefore, it is important to understand and validate the limitations of resolution on mapping data to correctly characterize the fibrillatory process.

Dr. Porta-Sánchez's collaboration was partially funded by "la Caixa" Foundation, Spain. This study was funded by CIHR operating grants and a Heart and Stroke Foundation Clinician Scientist Award to Dr. Nanthakumar.

Address reprint requests and correspondence: Dr. Kumaraswamy Nanthakumar, Division of Cardiology, Peter Munk Cardiac Centre, Toronto General Hospital, 200 Elizabeth St, Toronto, Ontario M5G 2C4, Canada. E-mail address: kumar.nanthakumar@uhn.ca.

The other commercial strategy that uses fibrillation from body surface ECGs utilizes the inverse solution and projects electrical activation onto the anatomic surface of the heart to identify critical drivers.^{18,19} These body surface techniques apply narrow bandpass filtering (BPF), usually centered on the highest dominant frequency (DF) of the surface ECG signals. Whether this selective filtering of electrograms truly represents the mechanism of myocardial fibrillation is unknown. It is also important to recognize that this filtering approach has not been validated against a reference standard (i.e., optical mapping), as it forces the signal acquired to be constrained to some *a priori* decided waveforms.

We studied the effect of spatial resolution and BPF on the location and characterization of rotors by comparing phase singularities (PSs) detected in phase maps with a reference standard of unfiltered optical maps (OMs) of fibrillating myocardium. We hypothesized that increased interelectrode spacing (lower resolution) and narrow BPF centered around DF could distort the interpretation of the underlying electrical organization in cardiac fibrillation.

Methods

All experiments were performed using rabbit Langendorff apparatus. The study was approved by the University Health Network ethics committee and was conducted following the guidelines for animal experimentation. Details about optical mapping and signal processing for map creation and examples of maps can be found in [Figure 1](#) and in the [Online Supplementary Videos](#) and [Online Supplementary Methods](#).^{20,21}

Signal processing and map creation

Phase maps and decimated phase maps

Phase maps of fibrillation were created by applying Hilbert transformation using custom written code on MATLAB (Mathworks Inc, Natick MA) on the optical data. Further custom written code created spatially decimated phase maps for each fibrillation optical dataset with predetermined reductions in resolution to simulate electrode spacing of 2, 5, and 8 mm (see [Online Supplementary Videos 1 to 4](#)).

Bandpass filtering

The DF of each pixel/fluorescence signal in each OM phase map was determined by applying a 2-dimensional periodogram in MATLAB. Bandpass filters were created at 4-Hz width centered on the upper quartile of DF of all pixels for each recording (see [Online Supplementary Videos 5 and 6](#)).

Characteristics of rotors

Localization, size, and stability of rotors

PSs were identified using custom written code on MATLAB. PSs lasting longer than the rotational cycle length were deemed rotors. The number of PSs and rotors over the 4-second recording period were counted. Temporal stability was analyzed by measuring the duration of PSs. Spatial stability was analyzed by measuring the sum of the longest

axis of PS displacement and the displacement at 90° to that axis. This metric was deemed the translation index.

In decimated phase maps, the accuracy of rotor localization was analyzed by measuring the minimal displacement of each rotor to a simultaneous rotor of the same chirality in the corresponding phase map at OM maximal resolution. Further analysis was made on this accuracy by assessing the proportion of rotors in decimated maps that fell within 5 mm of a simultaneous rotor in the OM. Five millimeters was selected because it represents a reasonable diameter for an irrigated radiofrequency (RF) ablation lesion, such that applying RF at the site suggested in decimated maps would affect a rotor core of the OMs.

Each identified PS had its rotational radius measured with custom MATLAB code calculating the maximum radius at which all action potential phases were present sequentially around the radius and rotating in continuity with the same chirality as shorter radii.

Definitions

Phase singularity (PS): Core of unexcited yet excitable tissue around which tissues at all phases of the action potential can be found. For the purpose of the study, only PS lasting > 30 ms were considered.

Rotor: Centrifugal wavefront around a PS. For the purposes of this research, a rotor was such a wavefront detected to rotate more than a full 360° cycle.

Rotational radius: Maximum distance from the PS to tissue demonstrating rotational activation as defined by all phases represented in circumference; phases in correct physiologic order; and rotation with the same chirality as the next shortest radius.

Translation index (TI): Measurement of spatial stability of phase singularity. TI is the sum of the longest axis of spatial displacement (of a PS) and the displacement at 90° to that axis in the x-y plane. A low TI is associated with higher spatial stability.

Duration of PS: Measurement of temporal stability. The time that a single PS continually fulfills the criteria defined above.

Mean proximity of detected PS to the reference optical map: Measurement of accuracy of detection of PS location in decimated phase maps. The proximity is the displacement between a PS detected in a decimated phase map and the nearest PS of the same chirality detected in the same frame of the OM phase map. Mean proximity is the mean displacement of the detected PS over its duration.

Statistical analysis

Statistics were analyzed using IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp. Nonparametric comparison of repeated measures was performed using the Friedman test with Bonferroni correction. Wilcoxon test was used to compare means between any 2 groups with non-normal distribution.

Download English Version:

<https://daneshyari.com/en/article/5603528>

Download Persian Version:

<https://daneshyari.com/article/5603528>

[Daneshyari.com](https://daneshyari.com)