Phase Singularities in Cardiac Patch Model with Non-conductive Fibrotic Area during Atrial Fibrillation

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Aims: Fibrosis creates heterogeneities in the cardiac tissue, favouring re-entrant activity driving atrial fibrillation (AF). Their relationship, however, remains controversial, and rotor detection related to fibrosis poses challenges. In the present work, *in-silico* cardiac patches with non-conductive fibrotic area were used to investigate the occurrence and characteristics of rotors described by phase singularities (PSs).

Methods: A stable rotational source was generated by cross-field stimulation in an isotropic virtual tissue patch. Membrane kinetics were represented by a Courtemanche model adapted to mimic AF conditions (conduction velocity: 0.22 m/s). Uniformly distributed fibrotic elements were incorporated around the centre of the patch (zero conductivity; fibrotic densities of 20%, 30% and 40%; Fig 1A). Electrograms (EGMs) were calculated in direct contact with the endocardial surface (8 s; 1 kHz). The phase of the EGMs was determined using Hilbert transform. PSs were detected using the topological charge method and PS density maps (PSDMs) were generated (Fig 1B). Bipolar EGMs (bip-EGMs) were obtained from the original signals (filter 30-300 Hz). The bip-EGMs were investigated using six markers: sample entropy (SampEn), determinism (DET), peak-to-peak (PP), wave similarity (WS), organization index (OI) and cycle length (CL).

Results: 77.1% of the PSs occurred inside the fibrotic region with a higher density in the border zone for 20% density; 99.8% for 30%; 99.7% for 40%. SampEn was significantly higher for bip-EGMs collected in regions with PSDM≥5, while DET, PP and WS were significantly lower ($P<0.0001$; Fig 1C). OI was significantly lower in PS regions for 30% and 40% densities ($P<0.0001$).

Conclusions: PSs tended to meander outside the fibrotic area for lower fibrotic density. The presence of PSs induced significant changes in the amplitude, dynamics and morphology of bip-EGMs. Markers for bip-EGMs offer a complementary way for rotor detection in the presence of non-conductive fibrosis.