Location of rotor and ectopic's atrial fibrillation mechanisms: a computational study using 2D Discrete Helmholtz Hodge Decomposition

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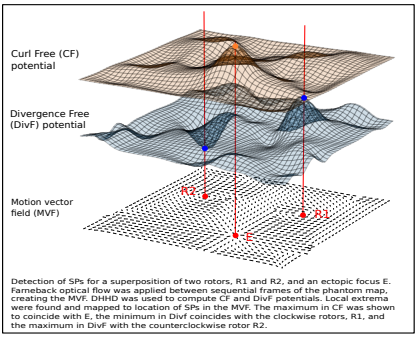
Aims: The Hodge-Helmholtz Decomposition (DHHD) is a tool for characterizing flow topology by decomposing a complex motion field into a curl-free (CF) scalar potential, a divergence-free (DivF) vector potential and a harmonic remainder. The proposed study aimed validation of DHHD for locating and identifying rotor and ectopic's atrial fibrillation mechanisms.

Method: 12 phantoms were created (128x128 array, 4 s, Fs 500 Hz), simulating the motion of: rotors (4), ectopic activity (4) and superpositions of these (4). First we applied Farneback optical flow (OpenCV-v4.5.5) to compute the motion of brightness patterns between adjacent time frames, then we found the CF and DivF potentials with the DHHD. The local extrema of the DivF potential were used for locating rotor and the CF potential for locating ectopic sources (local maxima). The robustness was tested by downsampling the phantom to 16x16 and 7x7, respectively, under different signal-to-noise ratios (SNR from 0.1dB to 60db). The surrogate maps are then upsampled with cubic interpolation to original sized array to allow investigation on its accuracy. In these maps, a mechanism is detected accurately if it is within 8% away from its respective original phantom.

Results: DivF maps showed higher absolute values near rotational sources, as the CF maps showed it around the ectopic sources (figure). For the 16x16 array, the accuracy reduced from 100% to 47.30%, by decreasing SNR from 60 to 1 dB, as well as for 7x7 (37.78% for 60 dB vs. 16.67% for 1dB). The superposition of different mechanisms appeared to have a great negative impact on the intensity presented at the extremes of the CF and DivF maps, especially in reduced layouts leads.



Detection of SPs for a superposition of two rotors, R1 and R2, and an ectopic focus E. Farneback optical flow was applied between sequential frames of the phantom map, creating the MVF. DHHD was used to compute CF and DivF potentials. Local extrema were found and mapped to location of SPs in the MVF. The maximum in CF was shown to coincide with E, the minimum in DivF coincides with the clockwise rotors, R1, and the maximum in DivF with the counterclockwise rotor R2.

Conclusion: This preliminary analysis shows that methods based on optical flow and DHHD allows localization and identification of rotor and ectopic mechanisms, even under high levels of downsampling and noise.