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Quantitative Comparisons of Different Approaches for Rotor Identification

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Abstract : Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia that is a known prognostic marker for stroke, heart failure and death. Reentrant mechanisms of rotor formation, which are stable electrical sources of cardiac excitation, are believed to cause AF. No existing commercial mapping systems have been demonstrated to consistently and accurately predict rotor locations outside of the pulmonary veins in patients with persistent AF. There is a clear need for robust spatio-temporal techniques that can consistently identify rotors using unique characteristics of the electrical recordings at the pivot point that can be applied to clinical intracardiac mapping. Recently, we have developed four new signal analysis approaches – Shannon entropy (SE), Kurtosis (Kt), multi-scale frequency (MSF), and multi-scale entropy (MSE) – to identify the pivot points of rotors. These proposed techniques utilize different cardiac signal characteristics (other than local activation) to uncover the intrinsic complexity of the electrical activity in the rotors, which are not taken into account in current mapping methods. We validated these techniques using high-resolution optical mapping experiments in which direct visualization and identification of rotors in ex-vivo Langendorff-perfused hearts were possible. Episodes of ventricular tachycardia (VT) were induced using burst pacing, and two examples of rotors were used showing 3-sec episodes of a single stationary rotor and figure-8 reentry with one rotor being stationary and one meandering. Movies were captured at a rate of 600 frames per second for 3 sec. with 64x64 pixel resolution. These optical mapping movies were used to evaluate the performance and robustness of SE, Kt, MSF and MSE techniques with respect to the following clinical limitations: different time of recordings, different spatial resolution, and the presence of meandering rotors. To quantitatively compare the results, SE, Kt, MSF and MSE techniques were compared to the “true” rotor(s) identified using the phase map. Accuracy was calculated for each approach as the duration of the time series and spatial resolution were reduced. The time series duration was decreased from its original length of 3 sec, down to 2, 1, and 0.5 sec. The spatial resolution of the original VT episodes was decreased from 64x64 pixels to 32x32, 16x16, and 8x8 pixels by uniformly removing pixels from the optical mapping video.. Our results demonstrate that Kt, MSF and MSE were able to accurately identify the pivot point of the rotor under all three clinical limitations. The MSE approach demonstrated the best overall performance, but Kt was the best in identifying the pivot point of the meandering rotor. Artifacts mildly affect the performance of Kt, MSF and MSE techniques, but had a strong negative impact of the performance of SE. The results of our study motivate further validation of SE, Kt, MSF and MSE techniques using intra-atrial electrograms from paroxysmal and persistent AF patients to see if these approaches can identify pivot points in a clinical setting. More accurate rotor localization could significantly increase the efficacy of catheter ablation to treat AF, resulting in a higher success rate for single procedures.

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