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Atrial fibrillation patterns are pre-processing method-based dependent

T Trevizan*[1], X Li[2], T P Almeida[3], F S Schlindwein[2], P Stafford[2], G A Ng[2], J Salinet

[1]Federal ABC University, São Bernardo do Campo, Brazil

[2]University of Leicester, Leicester, UK

[3]Instituto Tecnológico de Aeronáutica, São José Dos Campos, Brasil

**thalles.trevizan@aluno.ufabc.edu.br*

Background, Motivation and Objective. Atrial fibrillation (AF) is the most common arrhythmia in clinical practice and affects about 0.5% of the worldwide population. It causes significant morbidity and increased mortality with sufferers experiencing fast, irregular heartbeats or palpitation, breathlessness, dizziness or even blackouts and is considered the biggest factor of risk for cerebral vascular accidents. Once AF is initiated, dynamic alterations of atrial electrophysiological properties occur invoking, in turn, AF inducibility. In patients for whom AF persists for long-term periods (persAF), identification of critical areas for successful ablation remains a challenge. Dominant frequency (DF) ablation resulted in interatrial DF gradient reduction, prolonging patient's sinus rhythm. In addition, high-density DF mapping of persAF allowed recognition of dynamic spatio-temporal patterns, suggesting that ablation therapy is unlikely to be favoured by observing a single time frame. Investigators identified AF re-entry sources using phase analysis techniques in invasive and non-invasive electrophysiology systems. They also showed that targeting these sources appears to favour treatment success. Improving our understanding of the underlying AF behaviour is a key factor to contribute towards improving patient outcome. Modern commercial equipment has been developed to help clinicians identify and target patient-specific mechanisms responsible for AF maintenance, increasing patients' successful treatment rates. On the other hand, the systems' intrinsic methods limitations (number of electrodes and signal processing) have contributed to conflicting results on the fibrillatory mechanism. This study aims at analysing the impact of the pre-processing approaches currently used by commercial systems and clinical studies on the patients' phase maps outcomes.

Methods. 2048 simultaneous unipolar intracardiac electrograms (AEGs) with duration of 4 s were collected in the left atrium (LA) (Noncontact Mapping, EnSite System, St. Jude) of 4 patients with persAF before and after Pulmonary Vein Isolation (PVI) (Sampling frequency, Fs=1200 Hz). Firstly, cancellation of the ventricular influence on the AEGs was performed followed by other pre-processing steps where six different band-pass strategies were implemented: 1-150 Hz, 1-50 Hz, 1-15 Hz, 3-50 Hz, 3-15 Hz and at the highest dominant frequency (HDF, band of ±1 Hz) identified on the respective 3D DF map. The band-pass filters were implemented with a forward-backward Butterworth filter of order 10. Prior applying the high-pass filter, the AEGs were down sampled (fs= 40 Hz) and filtered and then up sampled to the original sampling frequency (1200 Hz). After, the AEGs were low-pass filtered with the predetermined cut-off chosen with the same previously described filter. Spectral analysis consisted of applying the Fast Fourier Transform (FFT) on the AEGs to identify the highest peak power (DF) within the physiological AF range (4 to 12 Hz). The 3D DF maps are generated by colour-coding the DF values on the 3D LA shell. 3D phase maps were obtained by applying Hilbert Transform on the AEGs and calculating the inverse tangent of the ration of imaginary and real parts of the analytical signal and limited between -π (depolarization) and π (repolarization). The points of singularity (SPs) were defined as the points around which the phase rotates by 2π and were automatically identified on the phase maps. Up to three neighbouring points radii and π/4 maximum step between neighbours were considered.

Results. Firstly, the number of SPs were reduced after PVI ablation showing the impact of substrate modification (15013 vs 14391, -4%). The number of detected SPs was shown to change when 1 or 3 simultaneous neighbouring points radii are considered (baseline: 15013 vs 6910, -117%), with a similar trend also for the post-PVI (14391 vs 5814, -148%). Moreover, the number of SP detected on the phase maps was shown to be method-dependent of filtering strategies (Figure 1), with fewer SPs identified as narrower the filter band applied: 1170±121 (1-150 Hz) vs 0.75±1.15 (HDF) (baseline and radii 1); 1130±108 (1-150 Hz) vs 0,25±0.50 (HDF) (post-PVI and radii 1); 557±106 (1-150 Hz) vs 0±0 (HDF) (baseline and radii 3); 470±112 (1-150 Hz) vs 0±0 (HDF) (post-PVI and radii 3).

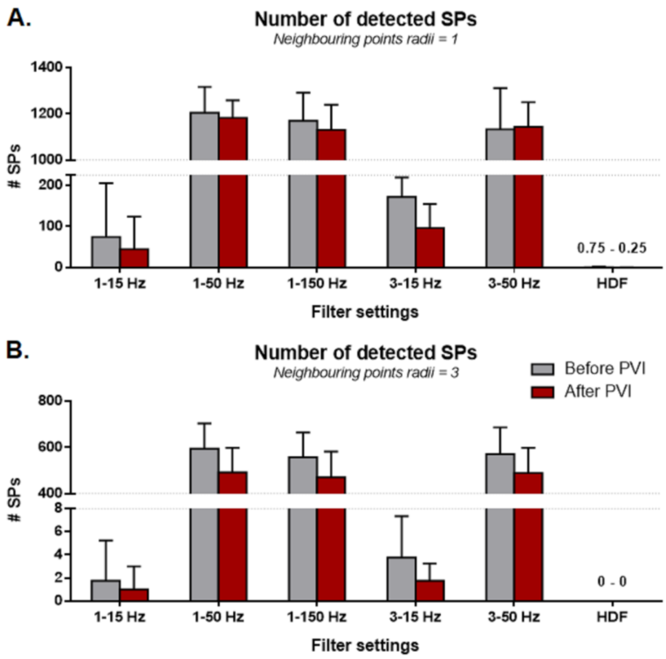

Figure 1: The impact on the SP detection on the phase maps according to the radii (1 and 3) and the pre-processing strategy (1-150 Hz, 1-50 Hz, 1-15 Hz, 3-50 Hz, 3-15 Hz and HDF ±1 Hz).

Discussion and Conclusions. The work proposed here highlights that the characterisation of fibrillatory phase patterns is extremely method-dependent making it difficult to represent the true electrophysiology of fibrillation. Current commercial technologies generate 3D maps making use of signal processing techniques similar to the ones implemented here and are used to identify and target areas on the atrium responsible for AF maintenance. This may be one of the factors that contribute to the controversies on the identification of the arrhythmic event maintenance mechanisms observed when comparing commercial systems.

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Keywords. Persistent atrial fibrillation; non-contact mapping; points of singularity; mechanism method-dependent.