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Time and frequency domain similarities of atrial activations during chronic atrial fibrillation

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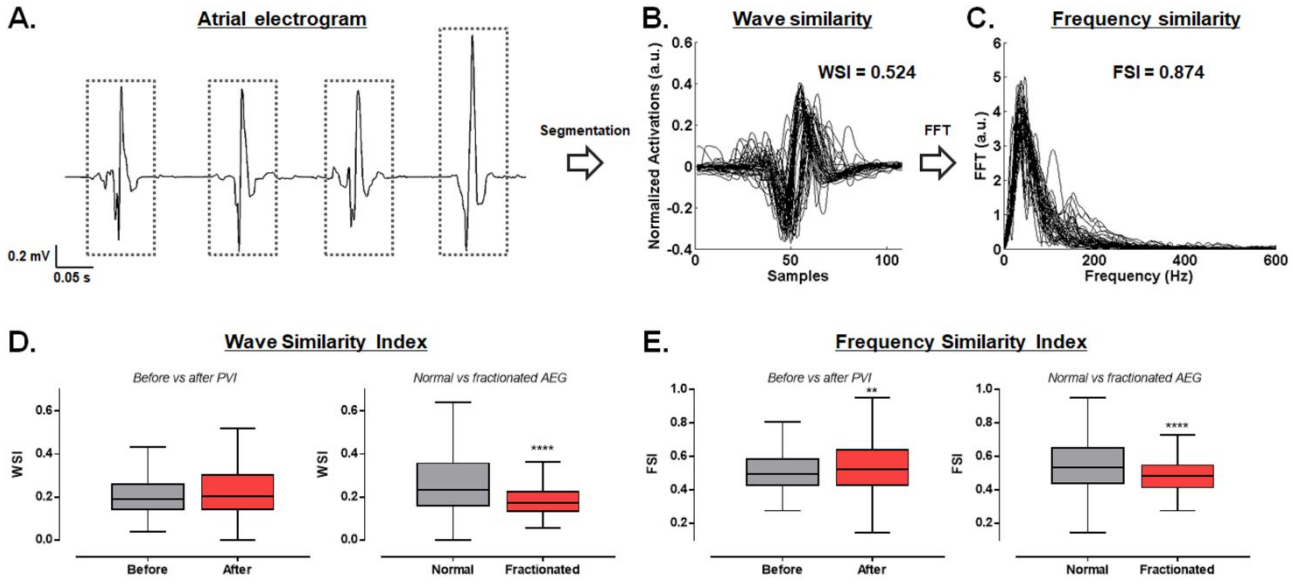
Background, Motivation and Objective. Atrial Fibrillation (AF) is the most common sustained cardiac arrhythmia found in the clinical practice. Pulmonary vein isolation (PVI) through radiofrequency catheter ablation is a cornerstone therapy for AF at early stages. PVI, however, has been shown insufficient for persistent AF (persAF) treatment, and additional ablation is usually required targeting atrial regions assumed to be involved in AF perpetuation. Such regions can be characterised by the presence of fractionated activity in atrial electrograms (AEGs, Figure 1A), but current commercial methods for automated atrial substrate classification have shown suboptimal ablation outcomes. Wave similarity index (WSI) has been previously introduced for AEG characterization in the time domain with promising results (Figure 1B). However, a similar analysis in the frequency domain is yet to be investigated. In the present work, we investigated the novel Frequency Similarity Index (FSI) as a marker for atrial substrate in persAF.

Methods. 797 bipolar AEGs (455 prior and 342 after PVI; 8 s duration; 1200 Hz sampling frequency) were exported, using the NavX system (St. Jude Medical), from 18 persAF patients undergoing PVI (Glenfield Hospital, Leicester, UK). AEGs with very low amplitude (≤0.03 mV) and contaminated with ventricular far field were removed from the study, resulting in 721 bipolar AEGs (434 prior and 287 after PVI). Automated AEG classification (normal or fractionated) was performed in all cases using CARTO criteria (Biosense Webster). CARTO calculates the Interval Confidence level (ICL), Average Complex Interval (ACI) and the Shortest Complex Interval (SCI). The AEGs were considered fractionated if ICL≥4, ACI≤82 ms and SCI≤58 ms. Based on CARTO evaluation, 414 AEGs were classified as normal and 307 as fractionated. WSI was calculated for all AEGs – using a previously published method – by detecting local activation waves, normalizing them and calculating the distance between pairs of activation waves through their inner product (Figure 1B). A modified version of such method was implemented to calculate a novel FSI, in which the fast Fourier transform (FFT) was applied to each activation wave, and the respective power frequency spectra were compared in a similar manner as in WSI (Figure 1C). The two markers (WSI and FSI) were investigated considering the PVI effect and CARTO classification. The Spearman correlation coefficient (ρ) between WSI and FSI was also calculated.

Results. High correlation was found between WSI and FSI (ρ=0.81, p<0.0001). WSI marginally increased following PVI (p=0.07), with significantly higher values for normal AEGs than for fractionated ones (p<0.0001, Figure 1D). Similarly, FSI increased after PVI (p=0.006), also with significantly higher values for normal AEGs (p<0.0001, Figure 1E).

Discussion and Conclusions. This work takes another step towards the characterization of persAF AEGs using organization markers in the time and frequency domain. The results show that both WSI and FSI were affected by PVI, and that the variables were effective in discriminating normal vs. fractionated AEGs. As expected, the increase of irregular activations on fractionated AEGs were reflected by dissimilar frequency content. However, FSI seemed more responsive to important electrophysiological phenomena, such as the changes in the electrophysiology of the atrial tissue induced by PVI. Our results show indeed that FSI discriminated pre and post-PVI AEGs better than WSI (p=0.006 *vs*. p=0.07), potentially offering a complementary perspective for characterising the underlying activation patterns. Future investigations in larger databases, where the underlying AF mechanism is previously known, will help to validate the use of these indices as adjunctive markers for atrial substrate characterization to guide persAF ablation.

Figure 1: A. Atrial waveform detection in an AEG collected at baseline. **B.** WSI and **C.** FSI calculation. **D.** WSI before and after PVI, and for normal vs. fractionated AEGs. **E.** FSI before and after PVI, and for normal vs. fractionated AEGs.



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