

Comparison of EGM Organization and Synchronization Indices in Atrial Fibrillation: a Simulation Study

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Atrial Fibrillation (AF) is the most common arrhythmia and is due to electrical re-entry or focal automaticity in the atria. Intracardiac electrogram signals, recorded at the atria walls, provide information about the local electrical activity.

In this work, we have used simulated EGM signals derived from real EGM to compare different organization and synchronization indices, based on spectral, cross-covariance, cross-information and wavefront analysis. To simulate EGM with different delays, signal-to-noise ratio (SNR) and activation variability in a realistic way, a good quality EGM was selected, and simulated EGMs were derived by delaying the signal, adding noise and adding a known amount of variability (σ) to the original activations times.

We studied three organization indices: the dominant frequency (f^D), the regularity index (I^R) and the organization index (I^O), five synchronization indices: the interquartile range and consistency of activation delays (C^{IQR} and CE), the averaged coherence ($|\Gamma|$), the maximum normalized cross-covariance (ρ), the maximum normalized mutual information function (ρ^I), and three delay indices: the median activation delay error (ϵ_μ), the lag of maximum cross-covariance (ϵ_τ) and the lag of maximum mutual information (ϵ_τ^I). To illustrate results, we present in the table the average results in four different simulated conditions (50 realizations for each one): SNR=15dB and $\sigma=0$ ms (no additional variability), SNR=15dB and $\sigma=20$ ms, SNR=0dB and $\sigma=0$ ms, SNR=0dB and $\sigma=20$ ms. Results show that wavefront analysis is much more sensitive to noise than other approaches to quantify synchronization. As for delay estimates, τ^I was the estimate with lowest bias and variance.

Mean values of the studied indices. ϵ_μ , ϵ_τ y ϵ_τ^I are the errors with respect to the true simulated delays.

	SNR=15dB, $\sigma=0$ ms	SNR=15dB, $\sigma=20$ ms	SNR=0dB, $\sigma=0$ ms	SNR=0dB, $\sigma=20$ ms
f^D	5.41 \pm 0.00 Hz	5.36 \pm 0.14 Hz	5.41 \pm 0.05 Hz	5.59 \pm 0.36 Hz
I^R	0.17 \pm 0.00	0.15 \pm 0.01	0.13 \pm 0.00	0.11 \pm 0.01
I^O	0.30 \pm 0.00	0.24 \pm 0.01	0.26 \pm 0.01	0.22 \pm 0.01
C^{IQR}	2.21 \pm 5.96 ms	40.28 \pm 22.75 ms	36.17 \pm 21.15 ms	37.24 \pm 13.38 ms
CE	0.89 \pm 0.10	0.31 \pm 0.23	0.45 \pm 0.20	0.37 \pm 0.21
$ \Gamma $	0.99 \pm 0.00	0.85 \pm 0.05	0.97 \pm 0.01	0.83 \pm 0.06
ρ	0.99 \pm 0.00	0.52 \pm 0.16	0.94 \pm 0.02	0.47 \pm 0.18
ρ^I	0.92 \pm 0.03	0.24 \pm 0.25	0.43 \pm 0.19	0.17 \pm 0.28
ϵ_μ	-0.00 \pm 0.02 ms	-9.72 \pm 12.07 ms	-31.74 \pm 29.43 ms	-38.72 \pm 28.27 ms
ϵ_τ	-0.01 \pm 0.03 ms	-0.68 \pm 3.66 ms	-0.03 \pm 0.09 ms	-1.57 \pm 4.38 ms
ϵ_τ^I	0.00 \pm 0.00 ms	-0.56 \pm 2.91 ms	-0.01 \pm 0.10 ms	-0.97 \pm 3.50 ms