ECG periodic components as a promising tool for complexity assessment during stepwise ablation of atrial fibrillation

A. Buttu[1], A. Viso[1], J. Van Zaen[1], JM. Vesin[1], A. Forclaz[2], P. Pascale[2], SM. Narayan[3], E. Pruvot[2]

[1]*Applied Signal Processing Group, Swiss Federal Institute of Technology EPFL,*

[2]*Department of Cardiology, University Hospital Center Vaudois CHUV, Lausanne*

[3]*University of California, San Diego*

Background

- Stepwise radiofrequency catheter ablation (step-CA) has become the treatment of choice for the restoration of sinus rhythm (SR) in patients (pts) with persistent atrial fibrillation (pers-AF).
- Its success rate appears limited as the amount of ablation to achieve long term SR is unknown.
- Recently, intracardiac organization indices (OI) of AF have been used to track the efficiency of step-CA, however with limited success.

Purpose

- Development of innovative OIs to improve the tracking of the efficiency of step-CA.

Methods

Study population

- 6 consecutive patients (61±4 y) with pers-AF (duration of sustained AF 16±10 months) underwent step-CA consisting in pulmonary veins isolation (PVI), defragmentation (CFAEs) and linear ablations as shown in figure 1.

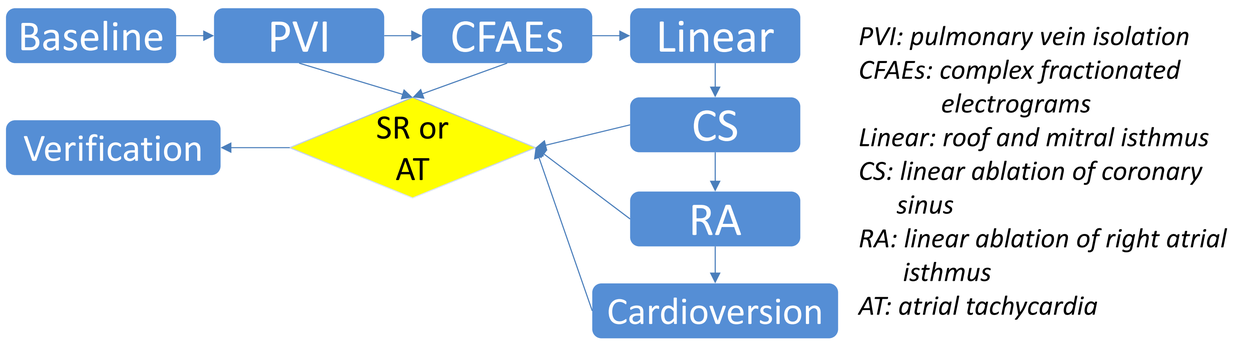

Figure 1: step-CA ablation protocol.

Signal Processing

- Based on a preliminary analysis, chest lead V_1 was chosen for estimating the instantaneous frequency of global atrial activity.
- Cancellation of QRST waves[1] was performed to compute a V_1 signal devoid of ventricular activity, on which a frequency analysis based on an adaptive tracking was applied.
- Figure 2 illustrates the tracking process on a synthetic signal for the extraction of the dominant frequency and its first harmonic component over time.

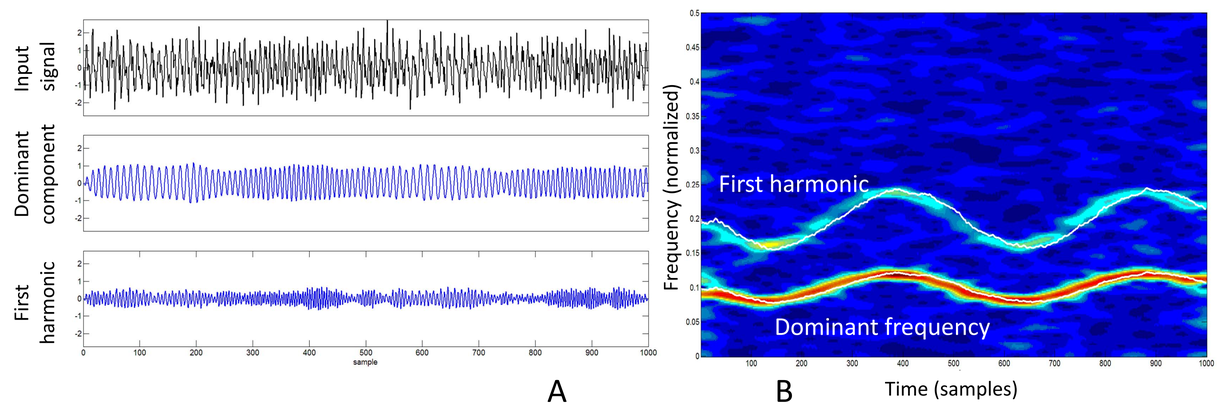

Figure 2: adaptive tracking algorithm. Panel A: synthetic signal (top) and its extracted dominant (middle) and first harmonic (bottom) components. Panel B: illustrates the ability of the adaptive algorithm to track the fluctuations of the dominant frequency and its first harmonic.

OI Parameters

1. Adaptive organization index (AOI) for the estimation of the temporal evolution of AF oscillations from lead V_1 defined as the ratio between the power of the extracted components and the total power of the signal.
2. Variance of the phase difference (PD) for the quantification of AF regularity between the dominant and harmonic components from lead V_1 defined as the variance of the slope of the PD.

Methods

OI Parameters - Example

Figure 3 shows an example of atrial activity from lead V_1 after QRST cancellation (top) and the resulting AOI (middle) and PD (bottom) parameters. Note the progressive organization of the ECG signal reflected as a gradual increase in AOI and decrease in PD.

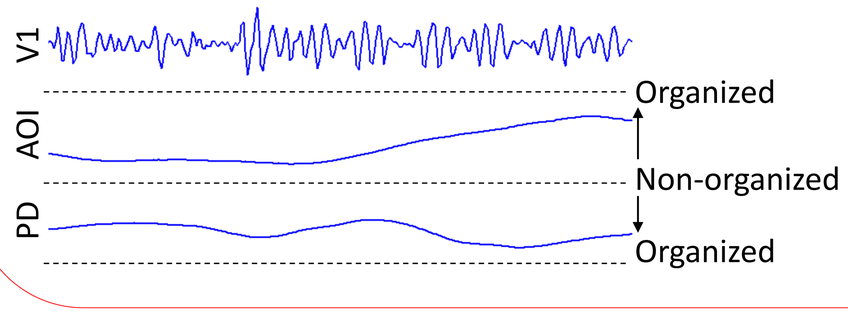

Figure 3: example of OI parameters. Top: V_1 free of the ventricular complexes. Middle: AOI. Bottom: PD.

Results

- Step-CA terminated 5/6 pers-AF into SR/AT.
- Figure 4 shows a representative example of a successful termination into AT during step-CA. Note the sudden increase in AOI during linear ablation. Importantly, the PD was more sensitive than AOI as it showed a early decrease during CFAEs representative of a phase locking between the AF dominant frequency and its first harmonic. In contrast, AF cycle length (AFCL) remained stable during the steps preceding AF termination.

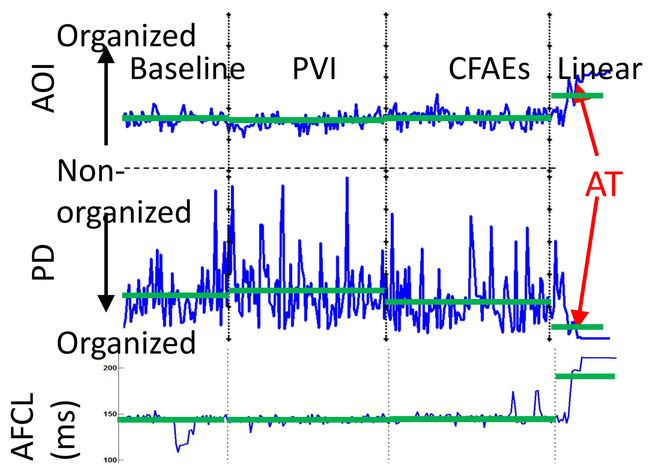

Figure 4: monitoring of the evolution of a stepwise ablation. Top, AOI. Middle, PD. Bottom, AFCL. AT, termination of AF.

Overall Study Population

- PD was more sensitive than AOI and AFCL for predicting AF termination, as shown in figure 5.
- The comparison between the last two steps preceding AF termination showed that PD decreased by 38±21% and AOI by 16±15% whereas AFCL did not change (0.6±3%).

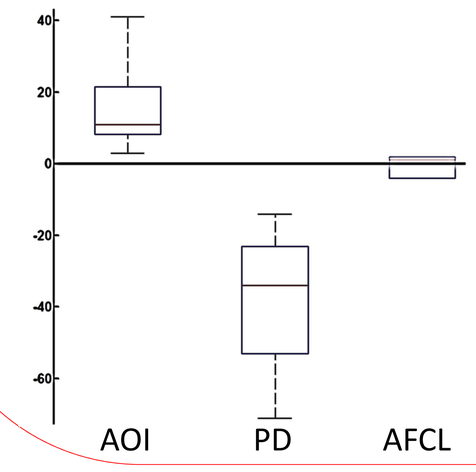

Figure 5: relative evolution in % during the last two steps preceding AF-term. AOI and particularly PD performed better than AFCL in all patients suggesting that increased coupling between the fundamental and the first harmonic of AF activity is an important feature to track the efficiency of step-CA "en route" to AF-term.

Conclusions

- The estimation of the AF dynamics from the surface ECG by means of AOI and PD appears as a sensitive measure for the tracking of AF organization during step-CA.
- Importantly, both PD and AOI improved the short term prediction of AF termination as compared to AFCL.
- These new indices might help to titrate the amount of ablation required to restore long term SR, but deserved further clinical validation and real-time implementation.

1. Lemay, Cancellation of Ventricular Activity in the ECG: Evaluation of Novel and Existing Methods – IEEE Transactions on Biomedical Engineering, 2007