# Adaptive Harmonic Frequency Schemes of Atrial ECG Reveal Divergent Patterns of Organization During Catheter Ablation of Persistent Atrial Fibrillation

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## Introduction

❖ Termination of persistent atrial fibrillation (pAF) by catheter ablation (CA) is associated with improved maintenance of sinus rhythm on the long term.

❖ Our study aims at determining whether the effect of stepwise CA (step-CA) can be tracked using organization indices based on the harmonic components of atrial ECG signals until pAF termination.

## Methods

❖ **Patients Characteristics and Data Acquisition**
• 34 consecutive patients (Table 1) underwent step-CA consisting in pulmonary veins isolation (PVI), left atrial (LA) defragmentation (CFAEs) and linear ablation[1].
• 40-sec epochs of ECG signal were recorded at baseline (BL), after PVI (end_PVI) and at the end of LA ablation (end_ABL).
• Chest lead $V_6$ was placed on the patients' back ($V_{6b}$).

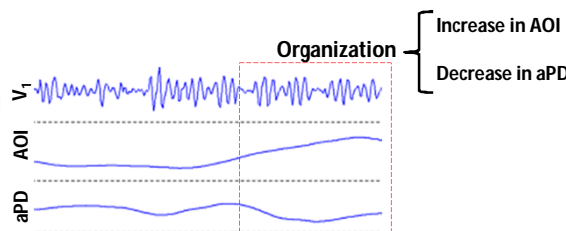| Clinical characteristics | Study population |
|---|---|
| Age (years) | 61 ± 7 |
| Male/Female | 32/2 |
| AF duration (years) | 6 ± 4 |
| Sustained AF (month) | 19 ± 11 |
| BMI (kg/m²) | 30 ± 6 |
| LA volume (ml) | 174 ± 44 |

**Table 1.** Clinical characteristics.

❖ **Signal processing**
• QRST cancellation was performed on ECG waveforms to generate atrial ECG signals devoid of QRST waves[2].
• The fundamental and its first harmonic components were extracted from the resulting signals using an adaptive frequency tracking scheme[3].

❖ **Organization indices**
• Adaptive organization index (AOI):
  - ratio between the power of the extracted components and the total power of the signal as an estimation of the temporal evolution of AF oscillations.
• Adaptive phase difference (aPD):
  - variance of the slope of the phase difference between the extracted components as an estimation of AF regularity.

Organization ⎱ **Increase in AOI**
        ⎰ **Decrease in aPD**

**Figure 1.** Example of organization measurements. Note the increase in atrial ECG signal organization on the right-hand side of the recording resulting in an increase in AOI and decrease in aPD values.
Top: $V_1$ lead devoid of QRST waves; Middle: AOI; Bottom: aPD.

## Results

❖ **Clinical Results**
• pAF was terminated in 68% (23) of the patients during LA ablation (LT - left terminated), while 32% (11) did not (NLT - not left terminated).
• The clinical characteristics were similar between the two groups except for a longer duration in sustained AF in NLT patients (Table 2).

| Clinical characteristics | Left terminated LT : 23 (68%) | Not left terminated NLT : 11 (32%) |
|---|---|---|
| Age (years) | 61 ± 8 | 60 ± 4 |
| Male/Female | 21/2 | 11/0 |
| AF duration (years) | 7 ± 5 | 4 ± 2 |
| Sustained AF (month) | 16 ± 8 | 25 ± 14* |
| BMI (kg/m²) | 30 ± 6 | 29 ± 7 |
| LA volume (ml) | 173 ± 44 | 175 ± 44 |

**Table 2.** Clinical characteristics for groups LT and NLT (* $p < 0.05$).

❖ **AF organization measurements**
• Figure 2 shows the temporal evolution of the organization indices measured on lead $V_1$ during step-CA in an LT patient (left) until pAF termination and in an NLT patient (right) at baseline, during PVI and LA ablation (CFAEs+Linear).
• Note the progressive organization occurring in the LT patient as depicted by the gradual increase in AOI and decrease in aPD during PVI and thereafter as compared to baseline. The NLT patient values remained stable over the entire procedure
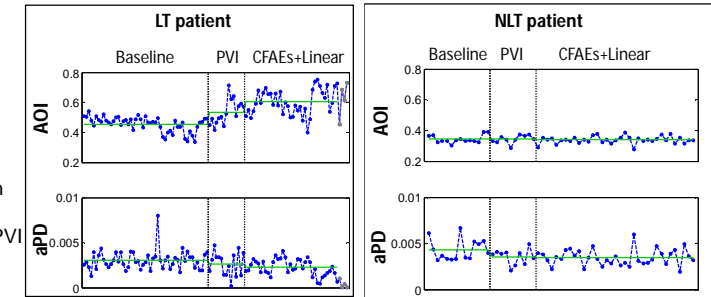
• Figure 3 shows the comparison of AOI and aPD values from lead $V_1$ and lead $V_{6b}$ between LT and NLT patients measured at baseline (BL), at the end of PVI (end_PVI) and at the end of LA ablation (end_ABL).
• LT patients displayed significantly higher AOI and lower aPD values at BL compared to NLT patients indicative of a higher level of atrial ECG organization that further increased significantly before pAF termination (Figure 3).
• Interestingly, both groups displayed a significant decrease in aPD during step_CA, but the level of organization in LT patients was significantly higher than that of NLT patients during entire procedure.
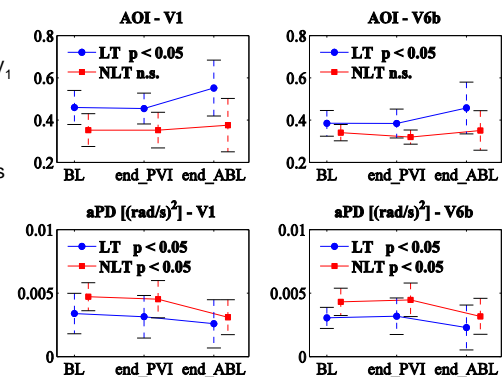
## Conclusion

❖ **The organization of atrial fibrillation during step_CA can be successfully track from the surface ECG** using adaptive frequency harmonic indices.

❖ **Distinctive temporal evolution of atrial ECG organization was observed between LT and NLT patients.** LT patients displayed a gradual ECG organization until pAF termination that was not seen in NLT patients.

❖ Organisation indices derived from adaptive harmonic schemes appear as promising metrics for tracking changes of AF dynamics induced by CA and prediction of procedural outcome.