Quantitative Assessment of Left Atrial Substrate of PsAF patients Using Functional Mapping, An Area-Based Observational Study

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Abstract

Persistent atrial fibrillation (PsAF) is associated with complex structural and functional remodeling of the left atrium (LA) that is not fully characterized by conventional sinus rhythm (SR) or atrial fibrillation mapping [1,2]. Functional mapping using triple extra-stimuli can unmask latent conduction abnormalities, including slow conduction and reductions in electrogram (EGM) voltage, linked to arrhythmogenic substrate [3–5]. This study quantitatively assesses these dynamic changes using area-based metrics derived from high-density electro-anatomical mapping.

24 PsAF patients undergoing LA functional mapping were analyzed. Local bipolar EGMs were processed using a threshold-based delineation algorithm to detect activation onset, with local activation time (LAT). LAT values were interpolated over a triangulated LA surface using a minimum Dirichlet energy solution, *Eq. 1*, enabling Conduction velocity (CV) derived from spatial gradients of smooth maps, *Fig. 1.II.*

$$Eq1 \qquad min_u\, E(u) = \frac{1}{2}\int_{\Omega} \|\nabla u(x)\|^2 dx$$

Low-voltage area (v<0.5 mV, LVA%), slow-conduction area (CV<0.5 mm/ms, LowCV%), and POS% were defined as the percentage of affected atrial area over the total mapped atrial surface. POS% represents the proportion of sites exhibiting a positive functional response to extra-stimulation, characterized by increased EGM duration and reduced voltage compared to SR. Functional response of EGMs was quantified as ΔLVA%.

POS% showed increasing correlation with LVA% across stimulation (First: ρ=0.37, p=0.07; Second: ρ=0.50, p=0.013; Third: ρ=0.60, p=0.002). Strong correlations were observed between POS% and LowCV% at all stages (First: ρ=0.73, p<0.001; Second: ρ=0.80, p<0.001; Third: ρ=0.76, p<0.001). Early functional response (First→Second) correlated with POS% for LVA (ρ=0.45, p=0.027) and LowCV (ρ=0.57, p=0.003), while late response (Second→Third) was not significant. Mean CV was inversely correlated with POS% (ρ≈−0.72 to −0.78, p<0.001), reflecting conduction slowing in diseased atria, *Fig. 1.III*

These findings demonstrate that functional substrate mapping reveals graded atrial remodeling, with early stimulation capturing the most clinically relevant dynamics and providing an objective framework beyond conventional mapping.

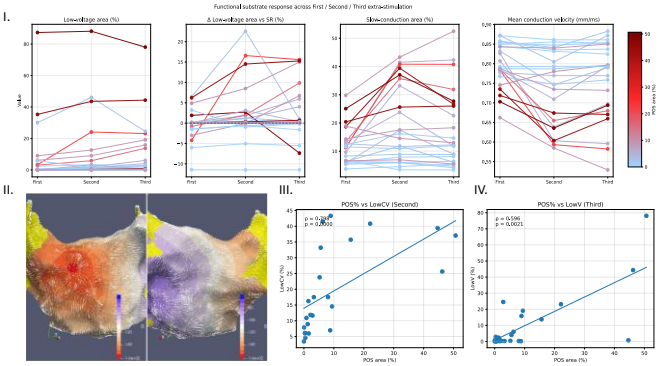

Figure 1. Functional substrate response across extra-stimulation. (I) Patient-wise changes in low-voltage area (LVA%), ΔLVA%, slow-conduction area (LowCV%), and mean conduction velocity from First to Third stimulation, color-coded by POS%. (II) Representative LA maps showing the voltage map and conduction velocity vectors. (III–IV) POS% correlates with LVA% at Third and LowCV% at Second stimulation, indicating the greatest Spearman coefficient and lowest p-values.

References

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