Characterizing Surface Fibrillatory Waves Through the Lagged Poincaré Plot for Preoperative Prediction of Ablation Success in Persistent Atrial Fibrillation

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Background and Aim. Atrial fibrillation (AF) management poses a significant challenge for healthcare systems due to the high mid–term recurrence rate following catheter ablation (CA) for persistent AF. Analyzing the morphological variability of fibrillatory waves (f–waves) from the electrocardiogram (ECG) has provided insights about the atrial electrical activity organization, which is a crucial indicator for CA outcome prediction. This work introduces an innovative analysis of f–waves morphology evolution over time based on the lagged Poincaré plot (PP) technique.

Methods. The surface ECG was preoperatively recorded before CA procedure for 52 persistent AF patients. Subsequently, 94 f–waves excerpts were extracted from the lead V1, obtaining 34 from patient that relapsed to AF and 60 for those who maintained SR after a follow-up period of 9 months. Traditional ellipse–fitting quantifiers and centroid–derived PP features were computed from the lagged PP representation of the f–waves for different lags ranging from 0 to 400 ms.

Results. The PP–derived features outperformed common CA outcome predictors, such as the dominant frequency (f_0) or the normalized amplitude of the f–waves ($n\mathcal{A}_{avg}$), and were comparable to the recently proposed power rate index (φ). Specifically, the minor ($SD1$) and major ($SD2$) axes of the optimally fitted imaginary ellipse, their ratio ($SD12$) and the standard deviation of the distance between PP points and the distribution centroid (S_d) showed a predictive accuracy (Acc) over 70%. Moreover, the combination of $SD12$, S_d, φ and $n\mathcal{A}_{avg}$ improved Acc and AUC up to 85% and 91.5%, respectively.

Conclusions. The Lagged PP has proven to be a valuable tool in characterizing f–waves, paving the way for a more personalized approach in AF treatment by preoperatively anticipating mid–term success of CA.

Index	SR group	AF group	p-value	m_{opt} (ms)	Acc(%)	AUC(%)
$SD1$	0.172 ± 0.031	0.207 ± 0.023	< 0.001	229	72.30	81.35
$SD2$	0.183 ± 0.026	0.222 ± 0.022	< 0.001	152	79.10	86.19
$SD12$	1.59 ± 0.21	2.07 ± 0.31	< 0.001	80	77.06	89.18
S_d	0.117 ± 0.009	0.126 ± 0.009	< 0.001	82	69.33	75.18
f_0 (Hz)	5.87 ± 1.21	6.29 ± 0.765	0.0140	–	60.45	62.75
φ	0.398 ± 0.243	0.164 ± 0.062	< 0.001	–	77.23	85.04
$n\mathcal{A}_{avg}$	0.237 ± 0.138	0.167 ± 0.080	0.0025	–	64.66	67.79