Sinus Rhythm P-wave Phenotyping for Identifying Latent Atrial Fibrillation Substrate in Veteran Endurance Athletes

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Atrial fibrillation (AF) related remodeling may persist during sinus rhythm (SR) and manifest as subtle P-wave abnormalities. Athletes exhibit increased AF risk and atrial adaptation. This study investigates whether P-wave features from SR ECG can identify latent AF electrophysiological signatures by distinguishing athletes with prior AF from those without.

23 male athletes with prior AF (AF-SR; 56.30 ± 5.63 y) and 20 male non-AF athletes (SR-SR; 56.55 ± 5.25 y) underwent 10-min resting 12-lead SR ECG (180 Hz). A 10-s segment per recording was analysed; P-waves were annotated on V3 across leads, yielding 328 beats. P-wave features were extracted and aggregated across beats; group differences were tested using non-parametric statistics with effect sizes. Classification was evaluated with logistic regression and random forest using five-fold cross-validation.

Compared with SR-SR controls, AF-SR athletes showed higher P-wave area variability (4.14 [3.80, 4.73] vs 5.94 [5.24, 6.34] mv.mv, $p < 0.0001$), P-wave energy variability (0.10 [0.085, 0.13] vs 0.20 [0.14, 0.22] mV^2, $p = 0.001$), P-wave amplitude variability (0.024 [0.022, 0.026] vs 0.035 [0.030, 0.038] mV, $p = 0.001$). Mean P-wave biphasic index (0.13 [0.10, 0.15] vs 0.09 [0.06, 0.10], $p = 0.002$). Random forest outperformed logistic regression (AUC 0.837 vs 0.815), with similar accuracy (0.77), higher F1 (0.81 vs 0.80) and sensitivity (0.83 vs 0.78), but lower specificity (0.70 vs 0.75).

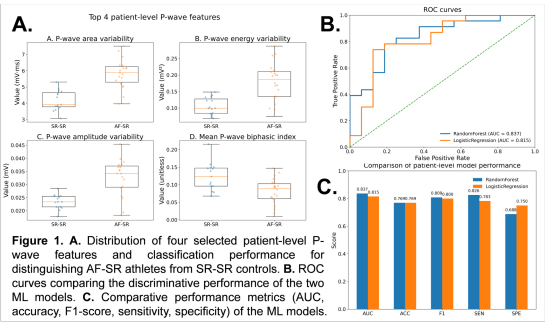

Figure 1. A. Distribution of four selected patient-level P-wave features and classification performance for distinguishing AF-SR athletes from SR-SR controls. **B.** ROC curves comparing the discriminative performance of the two ML models. **C.** Comparative performance metrics (AUC, accuracy, F1-score, sensitivity, specificity) of the ML models.

P-wave phenotyping during SR distinguishes athletes with and without AF history. Subtle abnormalities in P-wave magnitude, variability, and morphology may reflect latent AF-related atrial substrate even when in SR. In addition, machine learning models demonstrated promising discrimination, supporting the value of P-wave analysis as a noninvasive approach for AF-risk indication in athletic populations.