Patient-Specific Atrial Simulations Reproducing Clinical Electrogram Biomarkers Under Pacing Stress Protocol

Duna de Luis-Moura[1], Chiara Celotto[2], Saman Golmaryami[3], María Termenón-Rivas[1], Giada S Romitti[1], Santiago Moreno-Pineda[1], Etel Silva[3], Juan Fernandez-Armenta[3], José F Rodriguez[2], Alejandro Liberos[1], Miguel Rodrigo[1]

[1]CoMMLab, Universitat de València,València, Spain
[2]Department of Chemistry Giulio Natta, Politecnico di Milano, Milano
[3]Department of Cardiology, Hospital Universitario Puerta del Mar, Cádiz, Spain

Digital twins offer a framework to study atrial substrate, but their ability to reproduce intracardiac electrogram biomarkers used to guide therapy is not fully established. We analyzed five patients with persistent atrial fibrillation, projecting 1,363 clinical bipolar electrograms onto a patient-specific digital twin of the left atrium (Panel A). The model was calibrated using a triple extrastimulus pacing protocol, including adjustments of conduction properties and structural remodeling. This calibrated framework was then used to generate 21,527 simulated bipolar electrograms with integrated fibrosis. Electrograms were analyzed in a 290 ms window following a triple extrastimulus pacing protocol, extracting activation duration, number of deflections, and local activation time variability. Aberrant regions consistently showed increased activation duration in both datasets (simulations: 91 to 130 ms; clinical: 134 to 193 ms), together with consistent increases in deflections (sim: 5.6 to 7.4; clinical: 11.4 to 20.9) and LAT variability (sim: 3.5 to 5.8 ms; clinical: 11.4 to 21.9 ms) (Panel B). These findings demonstrate that patient-specific atrial models can reproduce electrophysiological patterns and may support identification of conduction abnormalities.