Continuous 4D Global Mapping Reveals Spatiotemporal Convergence of Atrial High-Rate Activity During Atrial Fibrillation

Adriana Costafreda[3]; Inés Llorente Lipe[3]; Raul Moreno[4]; Jana Reventós-Presmanes[1,3]; Berta Pellicer-Sendra[1,3]; Esther Guillen[3]; Ela Burrull[3]; Jean-Baptiste Guichard[1,2]; Andreu Porta[1,2]; Ivo Roca[1,2]; Eduard Guasch[1,2]; Andreu M.Climent[3,4]; María.S. Guillem3,4; Lluís Mont[1,2,5]; Felipe Atienza [3,5-7]; Till Althoff[1,2,8]

1Institut Clínic Cardiovascular (ICCV), Hospital Clínic, Universitat de Barcelona, Barcelona, Spain.
2Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain.
3Corify Care SL, Madrid, Spain.
4ITACA, Universitat Politècnica de València, Comunitat Valenciana, Valencia, Spain.
5Centro de Investigación Biomédica en Red (CIBERCV), Instituto de Salut Carlos III, Madrid, Spain.
6IISGM, Hospital General Universitario Gregorio Marañón, Madrid, Spain.
7Faculty of Medicine, Universidad Complutense de Madrid, Madrid, Spain.
8Department of Cardiology, Angiology and Intensive Care Medicine, German Heart Center of the Charité (DHZC), Berlin, Germany.

Introduction: Identification of atrial fibrillation (AF) perpetuating drivers remains a major challenge in AF ablation. We aimed to validate a novel non-invasive 4D mapping approach based on the spatiotemporal Stability of Atrial High-Rate Activity (SAHRA) to identify AF-perpetuating drivers.

Methods: Thirty-nine consecutive patients undergoing catheter ablation were prospectively mapped using the ACORYS system (Corify Care SL, Madrid, Spain). The SAHRA metric was computed across five-minute AF baseline recordings. Non-invasive electrocardiographic imaging (ECGi) was computed in consecutive 30-second segments and dominant frequency was extracted. Dynamic threshold set at the 90th percentile of global bi-atrial dominant frequencies defined SAHRA. SAHRA was iteratively computed over cumulative windows ranging from 0 to 300 seconds. Bi-atrial anatomy was parcellated into 12 standardized regions per EHRA consensus to quantify spatial AF driver distribution and intensity.

Results: SAHRA maps reached statistical convergence at 2.5 minutes ($p \geq 0.05$), establishing this as the minimum recording duration needed to reliably separate stable AF-perpetuating drivers from stochastic activity. Patients with more distinct driver regions exhibited higher SAHRA values, while high-complexity cases displayed more diffuse, transient multifocal activity. Spatially, the Left Atrial Appendage was the most frequently identified driver, present in 20 patients. However, the highest SAHRA intensity was concentrated in the LA inferior wall (36.5% ± 8.8%), LA lateral wall (35.5% ± 9.0%), and LA LPV (35.2% ± 7.6%). Results show AF-perpetuating activity is distributed across the bi-atrial anatomy, with stable driver sites identified not only in the left atrium but also in the right atrium, particularly the lateral wall and appendage, extending beyond traditional pulmonary vein locations.

Conclusion: SAHRA mapping establishes 2.5 minutes as the optimal threshold for identifying stable, AF-perpetuating drivers while integrating seamlessly into the clinical workflow providing a standardized, real-time framework for patient-specific AF characterization and targeted ablation.