Reinterpreting Complex Atrial Tachycardia Maps Using Global Atrial Vectors

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Editorial on: The Utility of a Novel Mapping Algorithm Utilizing Vectors and Global Pattern of Propagation for Scar-Related Atrial Tachycardias

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The mapping and ablation of Atrial Tachycardias (AT) can be challenging, particularly in patients with prior ablation or structural atrial disease. Entrainment is the foundation to confirm anatomically-based reentry but, in patients with structural disease, may transform or terminate AT. Activation mapping is thus often used in parallel. In recent years, high resolution catheters have increasingly been used to reveal micro-reentry at sites that appeared focal[1], to improve definition of gaps in scar or ablation lines[2]and to improve mechanistic definition[3]. In principle, it should be straightforward to use electroanatomical systems to mark electrograms and create isochrones for stable AT to guide ablation. In practice, it can be difficult to mark activation in electrograms that are fractionated or have low amplitude, which are common at sites of scar or prior ablation where AT often arise. It can thus be difficult to determine which activation sequence best represents arrhythmia and should be targeted for ablation. This remains a major clinical challenge, and there is a real need for objective tools to improve this interpretative process.

Using Global Atrial Patterns to Interpret Atrial Tachycardia Maps

In this issue of the *Journal* , Kuroda et al. [Kuroda JCE 2021 – Editor please insert] systematically evaluated the novel "Coherent^{TM}" algorithm that uses global patterns of propagation to resolve ambiguities in electrogram marking and create a "best-fit" map during stable arrhythmias. In N=77 patients with scar-related AT, the team retrospectively compared this novel algorithm with standard activation mapping, referenced to the gold standard of full clinical assessment (entrainment and acute ablation outcome). The novel algorithm more accurately determined AT location and mechanism (macro-reentry, localized reentry and focal tachycardia) in single (67.2% vs 44.8%, P=0.009) and dual-loop circuits than standard mapping, accurately reclassified mechanisms in cases when standard mapping failed, and reduced inter-observer variability.

Technical Approach

This global vector-based algorithm was first reported by Anter et al.[4] and has several components. First, the algorithm quantifies AT activation globally within the chamber, and uses these data to modify annotation of individual electrograms to produce a physiologically plausible final map. Second, the algorithm presents maps of vector propagation, that can differentiate focal or reentrant propagations from dead-end pathways, and of conduction velocity, that can identify slow conducting isthmuses of reentry. Finally, the authors write that the resulting activation map is independent of the mapping window, and displays color coded isochrones without predefined early and late activation (figure 1 from Anter et al. [4])

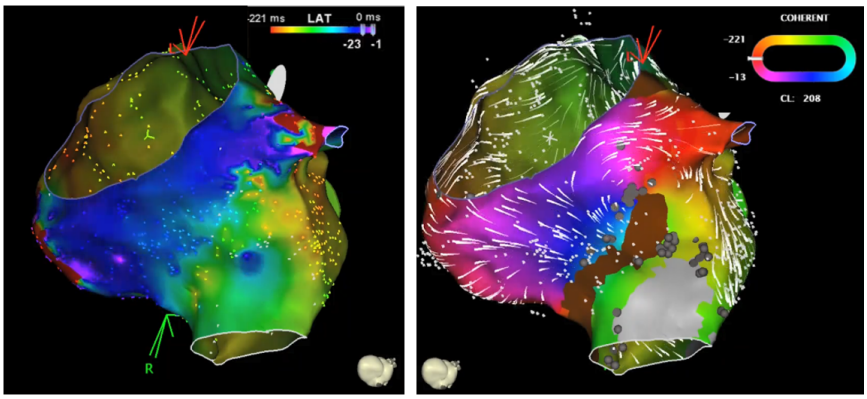

Figure 1. Comparison of standard activation mapping (left) and Global Vector Patterns (right). The Global Vector pattern algorithm shows localized reentry circuit with highly curved vectors of propagation, yet standard activation represented this tachycardia as a focal mechanism. Extracted from the Supplemental Material of Anter et al[4].

Critical Appraisal of Electrogram Re-Annotation by Global Vectorial Analysis

To solve the problem of assigning activation times for multi-component electrograms the algorithm identifies all possible markings, then selects that which best reconciles global activation (i.e. provides the lowest spatial and temporal errors). This is an elegant approach. However, it is not fully clear how selection is performed. If the algorithm uses rules (equations), their accuracy should ideally be reported for different types of rhythm and patient profile. If the algorithm uses more complex classifications including machine learning, the robustness of training labels is critical[5]. Global vectors are sensitive to regions that are over- or under-sampled, and so signal acquisition should be as spatially complete and uniform as possible. In theory, algorithmic selection could suppress potentially important mapping solutions, although such errors were not reported in this study. By optimizing maps globally, localized patterns with a small global impact such as micro-reentry with a small organized domain, could also be overlooked. The micro-reentry shown in figure 1[4] controls relatively large atrial areas, and it would be fascinating to study the sensitivity of this approach to smaller micro-reentrant domains. Extending this logic, it remains to be studied if the global vectorial approach could identify organized driver sites in AF, which may have local control yet a small impact on

global activation vectors, and for which several algorithms are in clinical testing[6-8].

How much information is needed to map AT?

A fundamental question in arrhythmia mapping is how much information is really needed. Kuroda et al. should be credited not only for performing a rigorous study, but also for acknowledging that the best results were achieved by methods "*combining activation mapping, entrainment and termination as determinants of true arrhythmia mechanisms"*[Kuroda JCE 2021 – editor to fill in]. One could imagine future algorithms using machine learning or rule-based logic to integrate multiple parameters such as electrogram amplitude to reflect vectorial direction, fractionated electrograms, beat-to-beat variability in cycle length or other characteristics. It is also important to compare this algorithm to other global vectorial approaches, such as those reflecting conduction velocity near scar [9] or those already applied to panoramic contact baskets[10, 11]. Each of these tests should ultimately be performed prospectively, and may need to be tuned for patients with or without prior ablation, with and without atrial structural remodeling, and so on.

In summary, the authors should be congratulated for this clinical study of a very innovative and physiologically plausible approach to provide 'automated interpretation' of electroanatomic maps in complex atrial arrhythmias. We look forward to future developments in this field.

References

1. Haddad ME, Houben R, Tavernier R and Duytschaever M. A stable reentrant circuit with spiral wave activation driving atrial tachycardia. *Heart Rhyhm* . 2014;11:716-8.

2. Sroubek J, Rottmann M, Barkagan M, Leshem E, Shapira-Daniels A, Brem E, Fuentes-Ortega C, Malinaric J, Basu S, Bar-Tal M and Anter E. A novel octaray multielectrode catheter for high-resolution atrial mapping: Electrogram characterization and utility for mapping ablation gaps.*J Cardiovasc Electrophysiol* . 2019;30:749-757.

3. Schaeffer B, Hoffmann BA, Meyer C, Akbulak RO, Moser J, Jularic M, Eickholt C, Nuhrich JM, Kuklik P and Willems S. Characterization, Mapping, and Ablation of Complex Atrial Tachycardia: Initial Experience With a Novel Method of Ultra High-Density 3D Mapping. *J Cardiovasc Electrophysiol* . 2016;27:1139-1150.

4. Anter E, Duytschaever M, Shen C, Strisciuglio T, Leshem E, Contreras-Valdes FM, Waks JW, Zimetbaum PJ, Kumar K, Spector PS, Lee A, Gerstenfeld EP, Nakar E, Bar-Tal M and Buxton AE. Activation Mapping With Integration of Vector and Velocity Information Improves the Ability to Identify the Mechanism and Location of Complex Scar-Related Atrial Tachycardias. *Circ Arrhythm Electrophysiol* . 2018;11:e006536.

5. Krittanawong C, Johnson KW, Rosenson RS, Wang Z, Aydar M, Baber U, Min JK, Tang WHW, Halperin JL and Narayan SM. Deep learning for cardiovascular medicine: a practical primer. *Eur Heart J* . 2019;40:2058-2073.

6. Baykaner T, Rogers AJ, Meckler GL, Zaman J, Navara R, Rodrigo M, Alhusseini M, Kowalewski CAB, Viswanathan MN, Clopton P, Narayan SM, Heidenreich PA and Wang PJ. Clinical Implications of Ablation of Drivers for Atrial Fibrillation: A Systematic Review and Meta-Analysis.*Circ Arrhythm Electrophysiol* . 2018;11:e006119.

7. Verma A, Sarkozy A, Skanes A, Duytschaever M, Bulava A, Urman R, Amos YA and Potter T. Characterization and significance of localized sources identified by a novel automated algorithm during mapping of human persistent atrial fibrillation. *J Cardiovasc Electrophysiol* . 2018;29:1480-1488.

8. Honarbakhsh S, Hunter RJ, Finlay M, Ullah W, Keating E, Tinker A and Schilling RJ. Development, in vitro validation and human application of a novel method to identify arrhythmia mechanisms: The stochastic trajectory analysis of ranked signals mapping method. *J Cardiovasc Electrophysiol* . 2019.

9. Caixal G, Alarcon F, Althoff TF, Nunez-Garcia M, Benito EM, Borras R, Perea RJ, Prat-Gonzalez S, Garre P, Soto-Iglesias D, Gunturitz C, Cozzari J, Linhart M, Tolosana JM, Arbelo E, Roca-Luque I, Sitges M, Guasch E and Mont L. Accuracy of left atrial fibrosis detection with cardiac magnetic resonance:

correlation of late gadolinium enhancement with endocardial voltage and conduction velocity. *Europace* . 2021;23:380-388.

10. Vidmar D, Narayan SM and Rappel WJ. Phase synchrony reveals organization in human atrial fibrillation. *Am J Physiol Heart Circ Physiol* . 2015;309:H2118-26.

11. Bellmann B, Zettwitz M, Lin T, Ruppersberg P, Guttmann S, Tscholl V, Nagel P, Roser M, Landmesser U and Rillig A. Velocity characteristics of atrial fibrillation sources determined by electrographic flow mapping before and after catheter ablation. *Int J Cardiol* . 2019.