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Coherent Mapping: A step toward physiological mapping of complex arrhythmias?

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Complex atrial tachycardias (AT) are commonly encountered in clinical practice either as a result of prior cardiac surgery[1], as a secondary consequence of substrate and linear based atrial fibrillation ablation[2], or de novo in the presence of advanced electro-anatomical remodelling associated with structural heart disease[3]. The mechanism of these ATs is typically macro-reentry but small circuit re-entry and focal tachycardias may also occur in relation to regional scarring. In the setting of advanced electro-anatomic substrate these circuits can be extremely challenging to map and ablate. Extensive regions of complex signals not necessarily involved in the tachycardia and multiple lines of conduction slowing and block can create the visual appearance of critical zones and circuits which are actually entirely passive[4]. These patients may also have multiple frequently changing and unstable circuits. Activation, voltage and entrainment mapping are the key approaches used in the electrophysiology lab to efficiently identify the circuit and more importantly, the critical isthmus. These approaches should be viewed as complementary: each has potential pitfalls and all require careful interpretation in the context of all the information. Three dimensional electroanatomic mapping with multi-electrode

catheters is now ‘standard’ and the collection of thousands of points per ‘map’ routine. However, accurate automated LA annotation of complex bipolar multicomponent EGM’s continues to present a challenge that to date lacks a reliable solution. Accurate map creation therefore demands meticulous manual assessment and re-annotation of complex electrograms in areas of slowed conduction that are often found at or adjacent to the critical isthmus. In the context of limitations which may mislead even the most experienced operator[4], entrainment mapping has continued to play a fundamental role in localising critical regions in order to focus the 3D map.

To overcome these limitations, Anter et al[5] recently described the utility of the Coherent mapping module and its ability to describe complex patterns of propagation to better define mechanism and guide ablation of complex atrial arrhythmias. This novel mapping algorithm (Coherent Mapping, Biosense Webster) aims to provide a physiological framework for 3D mapping by considering global patterns of activation, identifying areas of slow and discontinuous conduction so that the end user can understand complex re-entrant mechanisms and formulate an ablation strategy. The validation study showed that the algorithm was superior to standard LAT activation for both identification of the mechanism and predicting the site of termination of AT’s

In this issue of the Journal, Vicera et al[6] report their experience comparing Coherent mapping with standard activation maps in identifying the critical isthmus in patients with scar-related AT. In 20 consecutive patients, 26 complex AT’s (defined as AT occurring after previous cardiac surgery or ablation) were systematically mapped using a multi-electrode catheter. Using standard settings and definitions, activation, entrainment and Coherent mapping were performed, and an ablation lesion set was

defined based on the studied coherent map. In addition to comparing standard and coherent maps for all AT's, patients were also followed up to determine recurrence of arrhythmias.

Comparing coherent to standard LAT mapping the main findings of this study were four-fold: First, coherent mapping performed exceedingly well in identifying AT mechanism (100% vs 70%). Second, identification of critical isthmus/focal origin sites where ablation terminated the tachycardia was significantly more reliable (96.2% vs 69.2%, p=0.01). Thirdly, these critical isthmuses were narrower in dimension with Coherent mapping compared to 'standard' mapping allowing targeted ablation for AT termination. Finally, in patients who presented with multiple ATs, Coherent mapping was able to accurately identify two or three critical isthmuses in all cases whereas standard LAT maps identified 2 channels in only one quarter of maps.

The current study confirms the reported findings of the validation study by Anter et al[5] which showed Coherent-mapping algorithm allowed improved identification of simple and complex macro-reentrant circuits. Consistent with the study by Anter et al, the current study shows that the Coherent mapping module outperformed the legacy LAT mapping leading to a significantly higher rate of termination compared to the standard mapping (96% vs 70% respectively, $P<0.05$).

As the authors point out, the main limitations of the current study are the small sample size and the non-randomised nature of their comparison. The flutter recurrence rate of 15% during follow-up using the Coherent guided approach is comparable to previous studies[7-9] using conventional mapping and it therefore remains to be seen whether long term success rates will be higher. In the current study, approximately half of the ATs mapped were perimitral or roof dependent

circuits and it could be argued that a primary entrainment strategy complemented by standard 3D anatomy and voltage may have resulted in a similarly high success rate. In this study, entrainment was only possible in 70% of maps and as such it is unclear if Coherent mapping obviates the need for entrainment. Lastly, only stable tachycardias were included in the study. It is unknown how Coherent mapping would perform in challenging cases where there are often multiple (>3) alternating tachycardia circuits of varying cycle length. Nevertheless, the prospect that this more sophisticated mapping algorithm will facilitate ablation of complex circuits is tantalising and the authors are to be commended for this important contribution.

To understand the advantages and limitations of the novel Coherent mapping module it is important to consider the methodological aspects of the key elements that are incorporated into the Coherent algorithm. The initial input into the Coherent Algorithm is still the automated local activation time derived from the proprietary Wavefront algorithm. However, unlike the legacy LAT maps, the Coherent algorithm also compares the surrounding LAT times around each data point to generate a 'global' pattern of activation. As a result, uncertainties introduced by annotation of complex fractionated electrograms are in a sense 'smoothed' by assessing the totality of activation data both locally around acquired points and globally within a mapped chamber. In addition, as part of the initial Coherent mapping pipeline, the 3D surface geometry is divided into a fine mesh of small triangles (~0.5mm) i.e. discretization into a finite element mesh (FEM), reducing the magnitude of spatial interpolation related to errors in projection. In addition, the colour intensity of an individual point is now proportional to its distance from the nearest triangle, thereby further reducing spatial interpolation errors and improving the accuracy of generated maps.

The most novel feature of the Coherent module is the generation of conduction velocity maps based on key electrophysiological principles. The algorithm assigns each triangle on the reconstructed FEM with 3 descriptors: LAT value, conduction vector, and the probability of non-conductivity. Firstly, the 'raw' LAT times are parsed through the Coherent 'global solution' algorithm and each triangle assigned a 'Coherent' LAT that is then used to calculate a CV magnitude and vector using the known distances between triangles. The algorithm generates CV vectors for each triangle based on 3 physiological axioms 1. keep CV continuity by locally solving a least squares difference in CV between adjacent triangles; 2. Identify areas with conduction block <10 cm/s; 3. diverting or 'redirecting' the CV vectors around anatomical scar or areas of conduction block (SNO zones). The resultant CV map shows the relative CV values as arrows with thicker arrows representing relative slower conduction and thin arrows as rapid conduction.

In addition, the Coherent Algorithm removes the inherent bias created from setting a "window or interest' (WOI) and displays the Coherent activation map as a cyclical colour map based on the relative propagation between areas once the 'global' solution has been calculated, which is independent of the 'window or interest'. This removes the problem of the artificial 'early-meet-late' zone seen in legacy LAT maps. After the 'raw' LAT times have been parsed through the Coherent 'global' solution, the mapped chamber is then re-coloured so that the entire cycle length 'fills' the mapped area as shown in Figure 1. In this example of an activation map using global solution of a re-entrant atrial tachycardia in a patient with previous atrio-pulmonary Fontan, construction of activation map using global solution shows dataset within a localized region (inset) to have a distribution of values that comprise the entire cycle length of the tachycardia. This creates an appearance of a 'rotor' artefact. The region also

harbours complex fractionated electrograms as shown in Video 1. For an evenly distributed macro-entrant tachycardia where the entire cycle length of the circuit has been mapped, the earliest LAT point in the legacy activation map will most like match the Coherent starting point. In contrast, for a tachycardia where less than half of the cycle length has been mapped or where there are large gaps in data, the Coherent activation map may not have the same starting point as the legacy activation map. The algorithm may restructure the data set with a newly defined Coherent 'earliest value' or starting point.

There are some important limitations of the system. It is noteworthy that the Coherent maps are highly dependent on the point density, tagging of points and geometry reconstruction. In order for the 'global' solution to perform accurately, a minimum of 1500 points per map encompassing the whole chamber of interest is suggested. This can be time-consuming if there are multiple different circuits. In addition, the Coherent Algorithm is still dependent upon automated tagging of Scar based on user defined criteria **and** the manual tagging of Double Potentials, as the algorithm uses these tags as a way of contributing to the overall calculation of that area being a SNO zone. In contrast, complex fractionated electrograms should be manually tagged so that the operator can distinguish between zones of no conduction (scar and double potentials) and zones of slow conduction (long fractionated signals), however CFAE tagging is not used in the Coherent 'global' calculation. This is critically important to an understanding of where to ablate and to date the algorithm does not make this distinction. Furthermore, the Coherent algorithm does not display CV vectors within the designated SNO zone further limiting the operator's ability to identify the critical isthmus. One approach to assessing conduction within the SNO zone is to manually review the CV vectors entering and exiting putative channels or assessing the relative

thickness of the CV vectors around SNO zones. In our institution, manual review of the CV vectors around SNO zones are carefully analysed and thresholds set to ensure that the CV vectors are thick around the SNO zone. If the entire cycle length of a circuit is found within a SNO zone due to slowed conduction or the presence of complex fractionated electrograms, the Coherent-mapping algorithm may produce an artificial 'rotor'. This is because, by design, the algorithm diverts all CV vectors and activation around (rather than through) SNO zones. These artefacts occur in the setting of truly disorganized LAT times within a small area or can be the core of a localized circuit and should be interpreted carefully.

Like all new technologies, there is a definite learning curve for both the accurate interpretation and optimisation of the Coherent-mapping module. Despite the challenges and limitations, this study shows that the Coherent-mapping module is an improvement to previously available activation mapping and represents the latest iteration in automated mapping. As such, it has the potential to provide greater insights into the mechanism of complex AT circuits.

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FIGURE

Figure 1: Activation map using Global Solution: Voltage *(Panel A)* and Coherent isochronal map (50ms isochrones) *(Panel B)* of atrial tachycardia in a patient with previous atrio-pulmonary Fontan are shown. Construction of activation map using global solution shows dataset within a localized region *(inset)* to have a distribution of values that comprise the entire cycle length of the tachycardia. This creates an appearance of a 'rotor' artifact. ms: milliseconds, LAT: local activation time.