Validation Of An Algorithm For Automatic Arrhythmia Recognition And 3D Mapping In A Porcine Model

Peter Guerra[1], Jonathan Yarnitsky[2], Laurent Macle[1], Yannick Sablayrolles[3], Catherine Lavoie[1], Elad Nakar[2], Amir Ben-Dor[2], Meir Bartal[2], and Paul Khairy[1]

[1]Institut De Cardiologie de Montreal
[2]Biosense Webster Israel Ltd
[3]Biosense Webster Inc

March 30, 2022

Abstract

Introduction: Atrial tachycardias (AT) can present multiple sites of origin or circuits which complicates mapping, requiring creation of separate activation maps per site. Objective: To evaluate the Intra-Cardiac Pattern Matching (ICPM) software that automatically detects and assigns different arrhythmia sources to separate 3D activation maps in a porcine model. Methods: To simulate different ATs, continuous pacing at same cycle length was performed from 2-3 right atrial (RA) sites (2 screw-in leads and mapping catheter) for 60-90 seconds before alternating. RA was continuously mapped with a 48-electrode high-density mapping catheter (Octaray). The operator manually switched and added points to the respective maps when the AT changed. Conversely, the ICPM algorithm (Carto Mapping system) automatically assigned each beat to its respective map. Pacing electrodes were repositioned to create a second set of maps. Offline analysis (manual and automatic maps) was performed comparing local activation times (LAT) and mesh coloring values of adjacent points (<5 mm apart). Differences <10 msec were considered a match. Results: Twenty-three different pacing sites were analyzed in 6 swine with 1 manual/1 automatic map per site (46 maps); and 40,176 points were compared (manual and automatic). Individual LATs for manual and automatic maps were compared and matched 91.2% of the time (variance of <10 ms). Mesh coloring values matched using the same criteria. Conclusion: The ICPM algorithm accurately identified changing atrial activation sites and assigned points to appropriate maps >90% of the time compared to manual acquisition.

Validation of an Algorithm for Automatic Arrhythmia Recognition and 3D Mapping in a Porcine Model

Peter G. Guerra, MD*, Jonathan Yarnitsky+, Laurent Macle, MD*, Yannick Sablayrolles+, Catherine Lavoie, MS, CEPS*, Elad Nakar+, Amir Ben-Dor+, Bar-Tel Meir+ and Paul Khairy, MDCM, PhD*

* From the Electrophysiology Service, Montreal Heart Institute, Université de Montréal, Montreal, Canada; and + Biosense Webster, Yokneam, Israel

Correspondence : Dr. Peter G. Guerra, Montreal Heart Institute, 5000 Belanger Street, Montreal, Quebec H1T 1C8, Canada.

Email: peter.guerra@icm-mhi.org

Short title: ***Automatic Arrhythmia Recognition in a Porcine Model***

Word count: 1,199

Funding: This study was made possible by research support funding from Biosense Webster.

Disclosures: Authors listed with a + are employed by Biosense Webster. The research was supported by funding from this company.

All procedures performed in the study were approved by the Montreal Heart Institute Animal Ethics Committee in accordance with the Canadian Council of Animal Care (CCAC) Guidelines.

ABSTRACT

Introduction: Atrial tachycardias (AT) can present multiple sites of origin or circuits which complicates mapping, requiring creation of separate activation maps per site.

Objective: To evaluate the Intra-Cardiac Pattern Matching (ICPM) software that automatically detects and assigns different arrhythmia sources to separate 3D activation maps in a porcine model.

Methods: To simulate different ATs, continuous pacing at same cycle length was performed from 2-3 right atrial (RA) sites (2 screw-in leads and mapping catheter) for 60-90 seconds before alternating. RA was continuously mapped with a 48-electrode high-density mapping catheter (Octaray). The operator manually switched and added points to the respective maps when the AT changed. Conversely, the ICPM algorithm (Carto Mapping system) automatically assigned each beat to its respective map. Pacing electrodes were repositioned to create a second set of maps. Offline analysis (manual and automatic maps) was performed comparing local activation times (LAT) and mesh coloring values of adjacent points (<5 mm apart). Differences <10 msec were considered a match.

Results: Twenty-three different pacing sites were analyzed in 6 swine with 1 manual/1 automatic map per site (46 maps); and 40,176 points were compared (manual and automatic). Individual LATs for manual and automatic maps were compared and matched 91.2% of the time (variance of <10 ms). Mesh coloring values matched using the same criteria.

Conclusion: The ICPM algorithm accurately identified changing atrial activation sites and assigned points to appropriate maps >90% of the time compared to manual acquisition.

KEYWORDS

ablation, atrial fibrillation, atrial tachycardia, catheter ablation, intracardiac recordings, mapping

INTRODUCTION

Electrophysiologists are increasingly called upon to ablate more complex arrhythmia substrates. These can take the form of multi-site atrial tachycardias (AT), flutters, scar-related substrates in ventricular tachycardia, and nonautomatic focal AT or intra-atrial reentrant tachycardia (IART) in the congenital heart disease population [1, 2]. Areas of discontinuity in ablation lines can lead to proarrhythmic effects [3]. In patients post atrial fibrillation ablation, multiple focal ATs and reentrant flutter circuits can occur [4, 5], with 40% of recurrences attributable to ATs. In complex congenital heart disease such as single ventricle physiology with Fontan palliation, the mean number of inducible ATs/IARTs exceeds 2 per patient [6].

Three-dimensional electroanatomic mapping systems are indispensable tools for complex ablation procedures involving multiple sites of origin or circuits. Separate maps must be created for each arrhythmia which is challenging, particularly when arrhythmias transition from one site to another and/or have similar cycle lengths. Manual mapping can become cumbersome and subject to inaccuracies. The Intra-Cardiac Pattern Matching (ICPM) software (CARTO, Biosense Webster, Irvine, CA) was created to automatically identify tachycardia patterns and classify each to their respective maps. The software instantaneously recognizes changes in activation patterns thereby allowing continuous mapping of different arrhythmogenic foci/circuits. The purpose of this study was to systematically evaluate this algorithm in an animal model by comparing manually acquired and automated maps created by pacing at various atrial sites.

METHODS

Technology and algorithm

The ICPM algorithm distinguishes different atrial activation patterns based on unipolar signals recorded by the coronary sinus (CS) reference catheter. A weighted correlation mechanism applied to CS signals counters the effect of possible physiological changes on the signals' morphology, such as electrode tissue touch. Correlation is sensitive to catheter movements affect reference stability and excludes inappropriate mapping of ectopic beats. The algorithm filters unipolar signals to remove baseline wander caused by patient movement and respiration. A normalized correlation is then calculated for each channel (Pearson correlation). The channels are weighted based on the maximum slope of the pattern's signal, indicating how prominent each channel is. A correlation score is tabulated based on the weighted sum of calculated single channel correlations. Correlation values are calculated for each identified activation for a window surrounding the reference annotation using the user selected pattern of interest (POI). The final score is determined on the basis of the highest correlation value within that window.

Experimental methods

Six swine were induced with Pentothal 25 mg/kg, intubated, and maintained on a respirator with halothane. Venous access was obtained at 3 jugular and two femoral sites. Two screw-in leads were inserted from jugular sites, their positions captured on fluoroscopy and 3D mapping. Leads were subsequently repositioned to different pacing sites, simulating different focal arrhythmia sites with a minimal inter-electrode distance of 10 mm. Screw-in leads were used for greater stability and greater pacing consistency. A CS catheter was likewise inserted via jugular access. Mapping was performed using a high-resolution catheter with 8 spines and 48 electrodes (Octaray, Biosense Webster, Irvine, CA) inserted via the femoral veins (Figure 1). Additional pacing was performed via a mapping catheter in the femoral vein.

For each swine, continuous pacing at the same cycle length was performed at 2 to 3 different right atrial sites at least 10 mm apart for 60-90 seconds (Figure 1). In each animal, the electrodes were repositioned, and a second set of maps was created. The operator was aware of the change in pacing site and switched to the appropriate map manually. Manually created maps were optimised to best represent each pacing site through operator intervention. Using Carto Replay and retrospective Parallel Mapping, the same mapping time was processed using ICPM as an active filter, with the system automatically identifying the change in pattern (alternating pacing site) and assigning each pattern to its respective map, without operator intervention.

To validate ICPM performance and accuracy, each set of maps (manual and automated) for each pacing site were compared offline using two methods. Local activation times were compared with differences <10 msec considered a match. Only paired points within 5 mm of one another were included. Secondly, we compared interpolated color-coded activation maps generated from all available information in order to assess similarity between manual maps and those created by ICPM. For this comparison, both maps were based on the same mesh anatomy. Manual and automatically acquired maps were also qualitatively compared visually.

Statistical analysis

The proportion of automated points that matched the paired manual points with respect to local activation times and mesh vertices were calculated, along with corresponding 95% confidence intervals. Correlations between matched pairs were assessed by McNemar tests. Two-tailed P-values <0.05 were considered to indicated statistical significance. Analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 23 different pacing sites were studied in 6 swine, corresponding to 11 sets of alternating sites (Table 1). For each pacing site, manual and automatically acquired maps were created (total 46 maps). A total of 40,176 matched map points (mean 1747+-872 points per pacing site) and 97,912 matched vertices (mean 4257+-905 vertices per pacing site) were compared. Figure 2 illustrates comparative manual and automatic maps. A high concordance between local activation times translated into qualitatively similar map appearances. Visual comparisons revealed identical localization of the pacing sites between manual

and automated maps. Quantitatively, 91.2% of local activation times and 90.8% of mesh vertices showed consistency between the two maps as outlined in Table 1.

DISCUSSION

This study, in a controlled in-vivo environment, showed that the novel ICPM software was capable of accurately recognizing and mapping changing atrial foci. Whereas the operator was notified when the pacing site changed and switched maps accordingly, the software determined that the pacing site had changed on its own. Resultant maps were visually superposable. Quantitatively, local activation times and mesh vertices showed consistent matches >90% of the time. Pacing distances as close as 10 mm were assessed, and cycle lengths were kept constant to test the robustness of the system for distinguishing subtle differences in activation sites. This type of autonomous mapping capability could be of great benefit when targeting changing arrhythmia types, particularly in aforementioned conditions like atrial tachycardia, congenital heart disease and ventricular arrhythmias [7-9]. Additional advantages include automated filtering of mechanically induced ectopic activation that could introduce inaccuracies with manual mapping, particularly when cycle lengths are not radically different. Moreover, automated mapping can identify slight changes in signal morphology resulting from movements of the reference catheter that can otherwise go undetected.

LIMITATIONS

Whereas the pacing protocol was intended to mimic focal ATs, the ICPM software was not validated for reentrant arrhythmias. Also, considering these were healthy animals, it is unclear if the reliability of the automated algorithms would be affected by diseased conduction tissue. Finally, because the protocol was carried out in fully anesthetized and intubated swine, there were no undue movements. In a setting of conscious sedation, patient or catheter movements could have an impact on mapping procedures in general.

CONCLUSIONS

The current in-vivo animal data suggests that automation software for 3D electroanatomic mapping could reliably identify and map changing foci. This carries the potential to help localize different arrhythmia origins and increase efficiency in complex interventions that involve multiple arrhythmia substrates.

Q:\Secretariat Central\Publications\Chercheurs\Guerra,P\Validation\Validation JCE BriefCommunicat20201026PGap.docx

REFERENCES

1. Khairy P, Van Hare GF. Catheter ablation in transposition of the great arteries with Mustard or Senning baffles. Heart Rhythm 2009;6:283-289.

2. Khairy P, Stevenson WG. Catheter ablation in tetralogy of Fallot. Heart Rhythm 2009;6:1069-1074.

3. Chae S, Oral H, Good E, et al. Atrial tachycardia after circumferential pulmonary vein ablation of atrial fibrillation: mechanistic insights, results of catheter ablation, and risk factors for recurrence. J Am Coll Cardiol 2007;50:1781-1787.

4. Narayan SM, Baykaner T, Clopton P, et al. Ablation of rotor and focal sources reduces late recurrence of atrial fibrillation compared with trigger ablation alone: extended follow-up of the CONFIRM trial (Conventional Ablation for Atrial Fibrillation With or Without Focal Impulse and Rotor Modulation). J Am Coll Cardiol 2014;63:1761-1768.

5. Takigawa M, Derval N, Martin CA, et al. Mechanism of Recurrence of Atrial Tachycardia: Comparison Between First Versus Redo Procedures in a High-Resolution Mapping System. Circ Arrhythm Electrophysiol 2020;13:e007273.

6. Moore BM, Anderson R, Nisbet AM, et al. Ablation of atrial arrhythmias after the atriopulmonary Fontan procedure: mechanisms of arrhythmia and outcomes. JACC Clin Electrophysiol 2018;4:1338-1346.

7. Moore JP, Khairy, P. Adults with congenital heart disease and arrhythmia management. Cardiol Clin 2020;38:417-434.

8. Tzou WS, Frankel DS, Hegeman T, et al. Core isolation of critical arrhythmia elements for treatment of multiple scar-based ventricular tachycardias. Circ Arrhythm Electrophysiol 2015;8:353-361.

9. Choi Y, Kim S, Baek JY, et al. Acute and long-term outcome of redo catheter ablation for recurrent atrial tachycardia and recurrent atrial fibrillation in patients with prior atrial fibrillation ablation. J Interv Card Electrophysiol, 2020 Jun16. doi: 10.1007/s10840-020-00795-x.

Hosted file

`image1.emf` available at https://authorea.com/users/470838/articles/562707-validation-of-an-algorithm-for-automatic-arrhythmia-recognition-and-3d-mapping-in-a-porcine-model

Hosted file

`image2.emf` available at https://authorea.com/users/470838/articles/562707-validation-of-an-algorithm-for-automatic-arrhythmia-recognition-and-3d-mapping-in-a-porcine-model

Hosted file

`image3.emf` available at https://authorea.com/users/470838/articles/562707-validation-of-an-algorithm-for-automatic-arrhythmia-recognition-and-3d-mapping-in-a-porcine-model