Automated Localization of Atrial Ectopic Beats Using 12-Lead ECG Mean Spatio-Temporal Vector Position: Importance of Incorporating Patient-Specific Anatomic Models

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Background

Localizing the origin of atrial ectopic activity from the 12-lead ECG can be challenging, particularly in patients with atrial pathology.

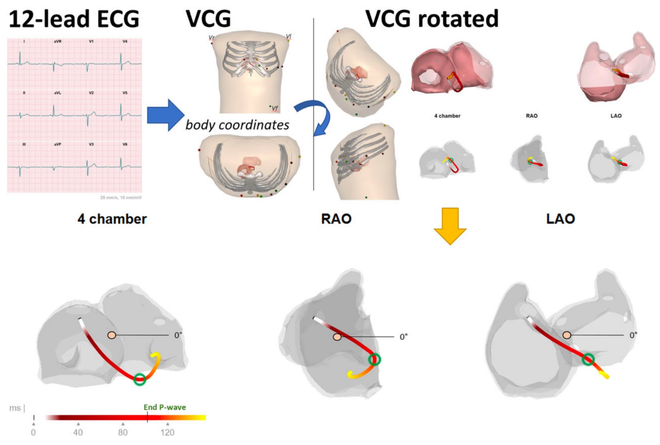
Objective

To identify the origin of paced atrial ectopic beats (simulating atrial ectopy) using software that quantifies the mean spatio-temporal vector position of cardiac depolarization projected onto generic and patient-specific atrial models.

Methods

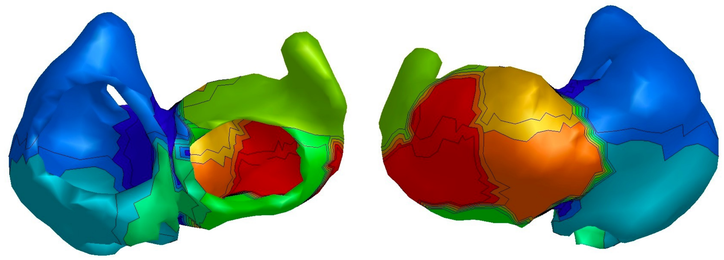
- 12-lead ECG data were collected during sinus rhythm (SR) and during regular pacing from the high and low right atrium (HRA/LRA), proximal and distal coronary sinus (CS), pulmonary veins (LSPV, LIPV, RSPV, RIPV), and left atrial appendage (LAA).
- The origin and trajectory of the atrial signals were calculated with software that analyzes P-waves from the 12-lead ECG and automatically constructs a net vector of electrical activity projected onto a standard generic model of human atria (CineECG; Nieuwerbrug, The Netherlands, **Figure 1**).
- The model atria were split into 9 segments, and the software accuracy was scored based on localization of the paced atrial signal origin to the correct segment (**Figure 2**).
- To see if patient-specific anatomy improved localization, we also incorporated atrial anatomy from cardiac MRIs acquired from a subset of 12 patients and compared localization to the generic model.

Figure 1: Calculation of CineECG



Locati ET, Pappone C, Heilbron F, van Dam PM. CineECG provides a novel anatomical view on the normal atrial P-wave. *Eur Heart J Digit Health*. 2022;3(2):169-180.

Figure 2: Atrial Segmentation for Scoring



LAO View

Posterior View

Demographics

- 19 patients (mean age 70±9)
- 4 females
- 63% paroxysmal vs. 37% persistent AF
- Baseline LA enlargement (mean LA volume 58 cc/m^2)
- All patients undergoing PVI

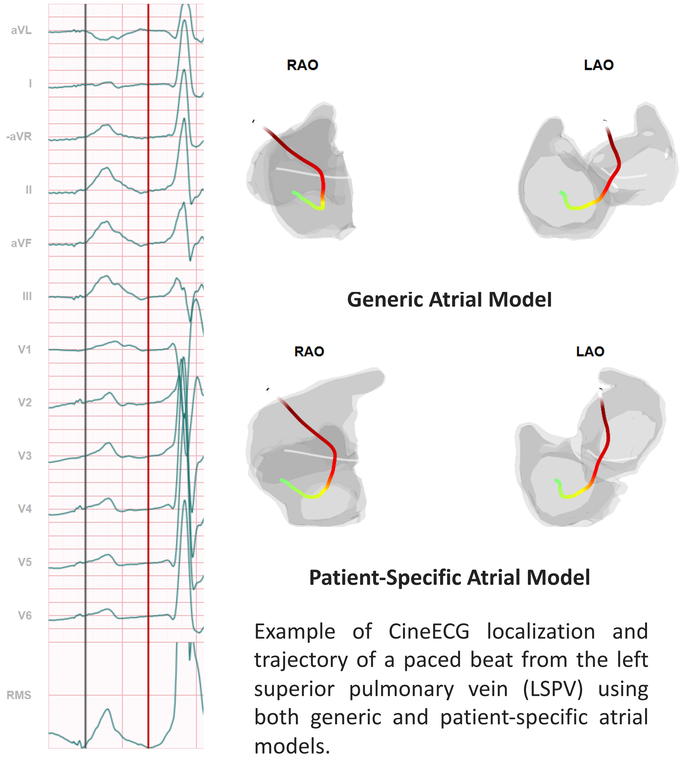
Results

- Using the generic atrial model, the software correctly localized 105/142 (74%) beats to the correct atrial segment (**Figure 4**). Accuracy was better for RA compared to LA signals (90% vs. 62%, $p < 0.05$).
- Localization worked best in the coronary sinus (19/19, 100%) and worst in the LPVs (14/33, 42%).
- Patient-specific models improved localization of PV signals, particularly left-sided ones (generic vs. patient-specific: RPVs 70% vs 85%, $p = 0.36$, LPVs 42% vs 76%, $p = 0.03$, **Figure 3**).
- Accuracy improved and was similar for RA vs. LA localization when using patient-specific models (90% vs. 82%, $p = 0.48$).

Conclusions

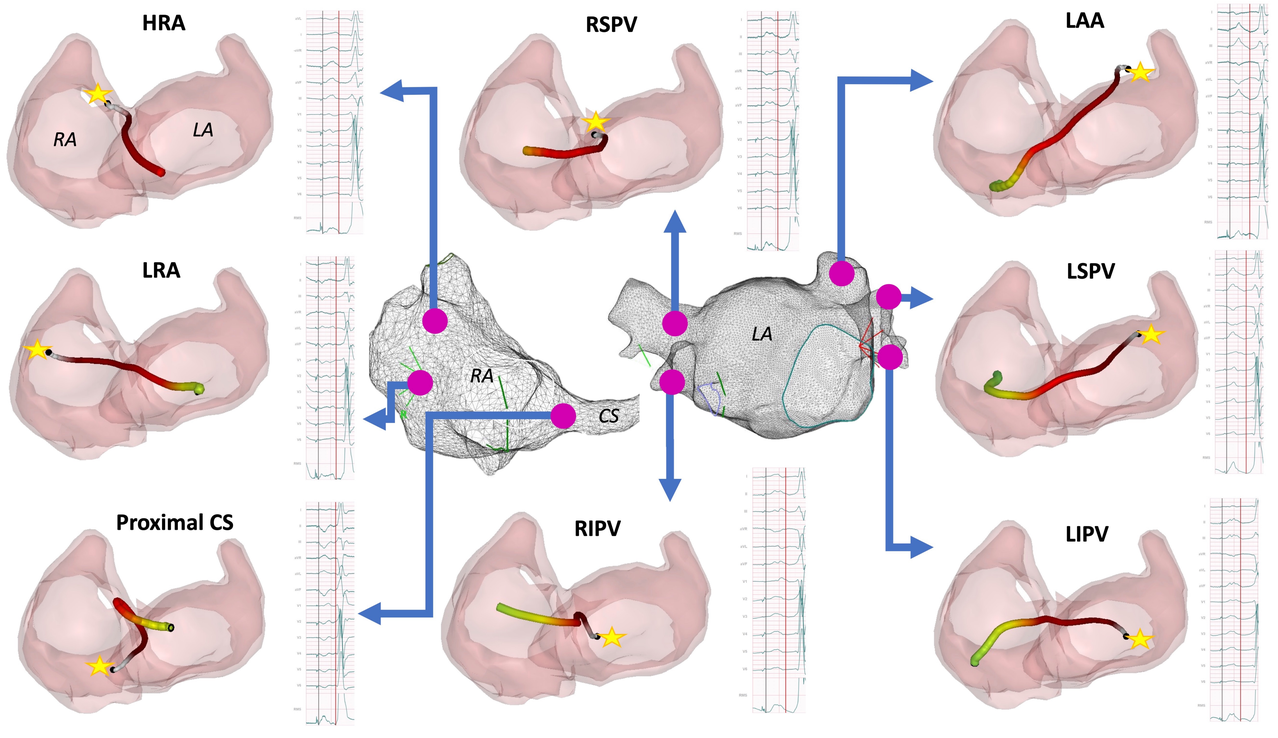
The novel software algorithm can automatically localize paced signals in both the left and right atria despite significant atrial pathology. Patient-specific anatomic models improve localization. This software holds promise for automatically localizing and classifying atrial arrhythmias and guiding therapy, including catheter ablation, based on standard 12-lead ECG data.

Figure 3: Example of Generic vs. Patient-Specific Atrial Localization



Example of CineECG localization and trajectory of a paced beat from the left superior pulmonary vein (LSPV) using both generic and patient-specific atrial models.

Figure 4: CineECG Localization of Various Paced Signals within the Atria



Pacing locations are depicted as pink dots on the right atrial (RA) and left atrial (LA) mesh images in the center. The software uses the 12-lead ECG signal of the P wave to quantify the mean spatio-temporal vector position of cardiac depolarization and projects it onto a generic atrial model. The origin is marked by the white end of the vector (marked as a star).