A Novel Method for Reconstructing Cardiac Action Potentials from Noncontact Cavitary Potentials: A Pilot Study

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Background

- The myocardial action potential (AP) is generated by the electrochemical action of membrane ion channels and represents the biophysical source of cardiac rhythm.
- Conventional cardiac mapping methods focus solely on depolarization by deriving local activation time (LAT).
- Reconstructing the full AP, including both depolarization and repolarization, offers clinically relevant insights into the dynamic mechanisms of arrhythmogenesis.

Objective(s)

Evaluate the accuracy of a novel method for reconstructing cardiac APs from noncontact (cavitary) potentials using simulated and preclinical data.

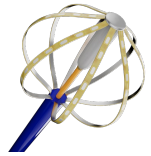
Methods

Simulation

- Thirty ground-truth focal activation patterns were simulated on MRI-segmented atrial meshes (1 left atrium and 1 right atrium) using a physiologically-realistic ionic model with rate-responsive AP duration (APD).
- Ninety-six noncontact unipolar electrograms were forward-computed and used to inversely reconstruct APs on the atrial meshes constrained by a biophysical shape-function and spatiotemporal continuity.
- Reconstruction accuracy was evaluated using morphology cross-correlation (XCorr), LAT error, and APD error.

Preclinical validation

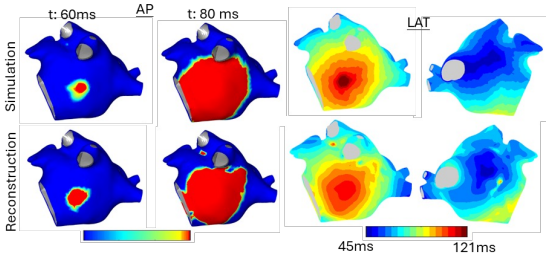
- Preclinical validation included contact and noncontact data acquired during 2 sinus and 3 paced rhythms using LibStar mapping catheter (96 electrodes, EnChannel Medical) in five swine.
- LAT maps of reconstructed APs from a single beat were compared with contact-based LAT maps from sequentially acquired from multiple beats.

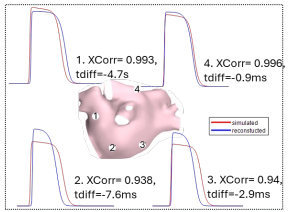


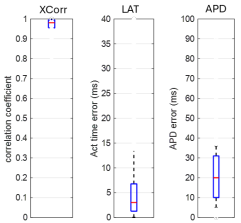
LibStar mapping catheter

Results

Simulation



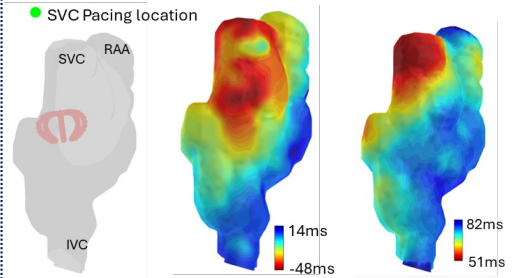




Reconstructed APs and LAT maps from simulation achieved

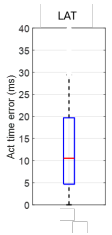
- XCorr of 0.980 (0.955-0.995),
- LAT error of 3.00 (1.25-6.76) ms,
- APD error of 20 (10-31) ms (13.33 (6.67-20.67) as % of APD).

Preclinical Validation



Contact Mapping
Time = 9 min 40 s
# points = 9288

Non-contact mapping
Single beat= 191 ms
points = 59



LAT maps derived from reconstructed APs in preclinical data were compared with contact-based LAT maps in paced rhythms with LAT error of 10.50 (4.67-19.69) ms.

Conclusion

- Novel AP mapping method accurately reconstructs APs in focal rhythms.
- Future research will evaluate and advance this method in complex arrythmias, including atrial flutter and atrial fibrillation.