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Dielectric-based imaging and navigation of the heart

Albert J. Rogers, MD, MBA, **Sanjiv M. Narayan, MD, PhD, FHRS**

Cardiovascular Division, Stanford University, Stanford, California.

Introduction

Electroanatomic (EA) mapping systems are increasingly indispensable for complex mapping and ablation procedures in electrophysiology. A wish list for EA mapping might include accurate, real-time acquisition of cardiac geometry; dynamic imaging of cardiac motion; localization of any catheters or wires within the heart; characterization of ablated vs nonablated tissue; and electrophysiologic identification of voltages, activation times, physiologic potentials, and arrhythmogenic indices. Few EA mapping systems meet these criteria. Geometric mapping is often referenced to computed tomography (CT; involving substantial radiation exposure) taken at 1 snapshot in time often weeks in advance, then edited manually for procedural use. Maps do not differentiate systole from diastole, which is problematic if catheters move due to mechanical systole or breathing but the digital shell does not. Furthermore, current systems may suffer from geometric inaccuracies due to nonlinear impedance fields or thoracic impedance drift,[1–5] and data from external systems such as intracardiac echocardiography, which could provide information on cardiac motion or blood flow/Doppler, often are not incorporated.

Dielectric imaging

In this issue of **Heart**Rhythm, Romanov et al[6] introduce dielectric imaging, an exciting new approach that may address some of the limitations of EA mapping systems and has the potential to change the way procedures are performed. The system produces 3-dimensional (3D) reconstructed tomography of the heart without the need for *a priori* CT or other imaging, can visualize any catheter, and has the potential to characterize tissue.

Dielectric imaging is performed by emitting low-energy radiofrequency (RF) waves at signature frequencies, such as 14 kHz with frequency separation of 100Hz,[7] from multiple electrodes or patches on the body surface. Localization is performed by triangulating electrode pairs with known spacing between nonparallel electric fields applied by multiple sources. This is conceptually similar to previous impedance-based methods[8] but incorporates fields delivered by other intracardiac electrodes in addition to body surface patches. Borders of the mapped chamber, such as the endocardial surface, vessels, or valves, introduce gradients in the electrical field that are recorded by intrabody and surface electrodes and represented in 3D. These boundaries improve with manual approximation of the intrabody electrodes to structures of interest.[9] These gradients may also potentially

Address reprint requests and correspondence: Dr Sanjiv M. Narayan, Cardiovascular Division, Stanford University, 780 Welch Rd, Suite CJ250F, Stanford, CA 94305, sanjiv1@stanford.edu.

represent structural characteristics based on dielectric permittivity and loss related to extracellular fluid, cell membrane qualities, or fibrosis, which could be used in future iterations. Data are acquired throughout the cardiac and respiratory cycles, binned, and combined to a point reflecting end-inspiration. Finally, 3D volumes are created based on known internal electrode distances and a model based on "matches in a sphere."[10]

The study by Romanov et al[6] presents preclinical stepwise validation of the technique to image cardiac anatomy in near-real time without previous CT, followed by early clinical imaging. The authors first validated the ability of the system to localize electrodes and measure distances *in vivo* in a swine model. The standard deviation of electrode localization was 0.35 mm (n = 576), showing stable, repeatable measurements over time, and the mean error of measured distances was 1.08 ± 0.11 mm ($P < .01$) vs known distances. Subjective comparison to CARTO 3 and CT images from the same animals revealed that dielectric-based maps were noninferior. Lastly, the authors evaluated maps in 22 patients undergoing ablation for paroxysmal atrial fibrillation (AF) in the DURABLE (Dielectric Unravelling of Radiofrequency ABLation Effectiveness)-I trial and found that images were acquired safely and efficiently with a high level of detail.

This study introduces several novel concepts with implications for future work. First, it would be useful to know how application of RF energy for ablation affects mapping, although in theory the distinct frequencies introduced by ablation could be filtered from those used for imaging. Second, it would be interesting to determine how tissue characterization by dielectric mapping during ablation compares to current surrogates of efficacy such as contact force. Third, it would be intriguing to study whether the time resolution of dielectric imaging is sufficient to resolve cardiac motion in real or near-real time. Fourth, the time needed to create a detailed map should be compared with existing EA mapping systems relative to the quality provided. The system could also be extended to pacing and resynchronization procedures, including wire mapping for imaging of the coronary venous system, for structural interventions to occlude the left atrial appendage, or potentially for catheter-based valve replacement. Indeed, the system may be available for imaging cryoballoons during pulmonary vein isolation.[11]

Limitations of this study include the fact that it was primarily performed in swine, and that human validation using the Likert scale was largely subjective. Second, although the DURABLE-I clinical study was performed in patients with paroxysmal AF, the majority (86%) were in sinus rhythm during mapping. Thus, whether accuracy is maintained in the fibrillating atria with irregularly irregular cardiac volumes and motion is unclear. Quantitative metrics from such human studies and comparison to existing EA mapping systems are eagerly awaited. Third, the current study assessed catheter location in a stable position for 20 seconds, which does not reflect real-world mapping. Finally, positional stability of the system should be established over time, given changes in thoracic impedance from ventilation, cardiac output, and fluid changes, and because measurements were not repeated over 1–2 hours.

Romanov et al[6] present dielectric imaging as an exciting new imaging approach with the potential to address several limitations of existing cardiac mapping tools. Their studies show

promising early *in vivo* animal validation of location and distance accuracy, and demonstrate safety in humans. We look forward to future studies showing how this approach can enhance current mapping methods to improve real-world ablation outcomes.

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References

1. Škňouřil L, Havránek Š, Bulková V, et al. Disparity between two-dimensional echocardiographic and electroanatomic left and right atrial volumes in patients undergoing catheter ablation for long-standing persistent atrial fibrillation. Physiol Res 2017;66:241–249. [PubMed: 27982678]
2. Heist EK, Chevalier J, Holmvang G, et al. Factors affecting error in integration of electroanatomic mapping with CT and MR imaging during catheter ablation of atrial fibrillation. J Interv Card Electrophysiol 2006;17:21–27. [PubMed: 17252200]
3. Okumura Y, Watanabe I, Kofune M, et al. Effect of catheter tip-tissue surface contact on three-dimensional left atrial and pulmonary vein geometries: potential anatomic distortion of 3D ultrasound, fast anatomical mapping, and merged 3D CT-derived images. J Cardiovasc Electrophysiol 2013;24:259–266. [PubMed: 23279593]
4. Kistler PM, Schilling RJ, Rajappan K, Sporton SC. Image integration for atrial fibrillation ablation—pearls and pitfalls. Heart Rhythm 2007;4:1216–1221. [PubMed: 17765625]
5. Issa ZF, Miller JM, Zipes DP. Clinical Arrhythmology and Electrophysiology: A Companion to Braunwald's Heart Disease, Third Edition. Philadephia, PA: Elsevier; 2019.
6. Romanov A, Dichterman E, Schwartz Y, et al. High-resolution, real-time, and nonfluoroscopic 3-dimensional cardiac imaging and catheter navigation in humans using a novel dielectric-based system. Heart Rhythm 2019;16:1883–1889. [PubMed: 31255845]
7. Ben-haim S, Ibragimov Z, Yehonatan BD. Intrabody Probe Navigation By Electrical Self-Sensing. 2018 Patent WO 2018/146613 A2; 2018.
8. Wittkampf FHM, Wever EFD, Derksen R, et al. LocaLisa: new technique for real-time 3-dimensional localization of regular intracardiac electrodes. Circulation 1999;99:1312–1317. [PubMed: 10077514]
9. Ben-Haim S Field Gradient-Based Remote Imaging. 2019 Patent WO 2019/035023 Al; 2019.
10. Dichterman E, Ben-haim S. Reconstruction of an Anatomical Structure From Intrabody Measurements. 2019 Patent WO 2019/034944 Al; 2019.
11. Groves M, van der Feer F. Philips announces collaboration with Medtronic to further advance the image-guided treatment of atrial fibrillation. GlobeNewswire 2019, http://www.globenewswire.com/news-release/2019/05/09/1820949/0/en/Philips-announces-collaboration-with-Medtronic-to-further-advance-the-image-guided-treatment-of-atrial-fibrillation.html. Accessed July 6, 2019.