BRIEF REPORT

Preclinical experience using 4-dimensional intracardiac echocardiography with CARTO integration

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Current electrophysiology (EP) standard-of-care practice for left atrial appendage occlusion commonly uses transesophageal echocardiography (TEE). Prolonged TEE typically requires general anesthesia, which may increase procedural risk, hospital resource utilization, and duration of hospitalization.[1–3] Standard 2-dimensional (2D) intracardiac echocardiography (ICE) has replaced TEE for intraprocedural imaging in advanced EP mapping and ablation procedures, and incorporation of a sensor on 2D ICE catheters, which allows for 3-dimensional (3D) image integration, has maximized the capacity of intracardiac visualization.[4] High-definition 4-dimensional (4D) ICE integrates real-time 3D ICE imaging to produce high-quality dynamic volumetric images for better visualization of cardiac structures without the need for TEE and general anesthesia.[5] A novel ICE catheter, with independent tip rotation knob, allows the user to rotate the transducer of a 10-F steerable catheter (crystal steering) without catheter handle manipulation for optimal tip orientation and stable acquisition, enabling a single-handed workflow. This catheter has been described previously.[6–8] The sensor integration of 4D ICE with 3D electroanatomic mapping allows multiplane imaging with reduced catheter manipulation. Using software algorithms and 4D ICE imaging to create volumetric structural images enables more comprehensive visualization during EP procedures.

We assessed the feasibility of using the novel NUVISION NAV Ultrasound Catheter (ICE NAV catheter, Biosense Webster, Irvine, CA) with a mapping sensor for visualizing volumetric multiplane images, real-time ablation catheter tracking, and 4D views on the mapping system in a porcine model.

Care and use of animals in this report were approved by the Institutional Animal Care & Use Committee and conformed to the Position of the American Heart Association on the Use of Research Animals and the guiding principles of the Declaration of Helsinki.

The left femoral vein was cannulated using an 11-F short sheath to accommodate the 10-F ICE NAV catheter, which is compatible with the CARTO 3 system (Biosense Webster) and GE Vivid S70N (GE Healthcare, Chicago, IL). The ICE NAV catheter was advanced into the right atrium (RA) using ultrasound imaging only. The right femoral vein was cannulated for ablation catheter access.

CARTOSOUND 4D (Biosense Webster) was used in the workflow when using the ICE NAV catheter. The CARTOSOUND beam was clocked and counterclocked using the crystal steering knob (ie, probe knob) to visualize biplane and triplane imaging. The catheter was placed in the RA, home view was obtained, and then the catheter was slightly anteriorly deflected and crystal steered counterclockwise to visualize the crista terminalis and superior vena cava in 1 view. The crista terminalis was visualized in ultrasound with biplane and 4D ultrasound imaging and superimposed with the RA map on mapping software. The mapping software algorithm, coupled with independent tip rotation, supports the ease of visualization of the crista terminalis with biplane and 4D imaging (Figure 1A, left). Although biplane imaging can provide the secondary view of the ablation catheter, the 4D image with ablation catheter tracking can facilitate the user in determining catheter stability and gaps in ablation lesions. In the left atrium, the triplane image position was optimized near the interatrial septum to facilitate full chamber anatomy map reconstruction without additional catheter manipulation. The contour of the inferior pulmonary veins was drawn using triplane imaging with the mapping software to generate a 3D map, which also showed the left atrial appendage (Figure 1A, right, Supplemental Video S1).

Doppler flow imaging can also be obtained in multiplane modality. Blood flow can be delineated clearly through the left veins (Figure 1B, left). The 2D ICE image view enhances the color Doppler feature for the quality detection of blood flow, leakage, and complications.

The ICE NAV catheter was also used for real-time ablation catheter (THERMOCOOL SMARTTOUCH SURROUND

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KEY FINDINGS

- The article describes rationale of improvements on imaging during catheter ablation and left atrial appendage occlusion procedures, when using 4D ICE technology in comparison to 2D ICE and TEE.
- Procedures using 4D ICE technology provide volumetric data compared to a “single slice” of ultrasound as with the standard 2D imaging catheters. This volumetric data has previously only been available with TEE necessitating general anesthesia.
- This new 4D ICE technology allows for more comprehensive yet faster ultrasound structure demarcation and ultrasound map creation with decreased catheter manipulation thereby less operator dependent for improved ultrasound visualization and anatomy shell creation.
- Improved efficiency on manipulation is due to independent tip rotation which allows the user to rotate the transducer without catheter handle manipulation. This enabling single-handed workflow and imaging in a 360 degree fashion from a single catheter location.
- Improved mapping efficiency is due to sensor integration of multiplane 3D ultrasound imaging with 3D electroanatomic mapping (EAM). This allows catheter localization within a 3D EAM to facilitate map creation using volumetric data.

FLOW [STSF] Catheter, Biosense Webster) tracking. Visualization of the superior vena cava, RA appendage, and ablation catheter (Figure 1B, right) was shown by advancing the ablation catheter and positioning it into the volumetric image created by the ICE NAV catheter. The 2D ultrasound image tracks the ablation catheter in the entire volume captured by the ICE NAV catheter. The axis was switched from the short to long axis electronically via the GE Vivid S70N system, which can only be performed in the multiplane mode. The papillary muscles and septum were also visualized.

Improvements in technology over the years have led us from TEE to using ICE to visualize cardiac structures, continuing from 2D to 4D ICE with the added benefit of crystal steering. There is a growing interest in using 4D ICE for EP procedures, such as catheter ablation procedures. This case report demonstrated the feasibility of using 4D ICE to better visualize anatomical structures in volumetric multiplane view on the map, ablation catheter tracking, and performing crystal steering in a preclinical model. A novel independent transducer tip rotation knob allows the acquisition of images more easily with 360° rotation, and multiplanar imaging allows the visualization of multiple target structures with less catheter manipulation. These tools could ease the overall imaging workflow in a clinical setting. Further clinical experience is needed to assess the diagnostic value of the ICE NAV catheter in human patients.

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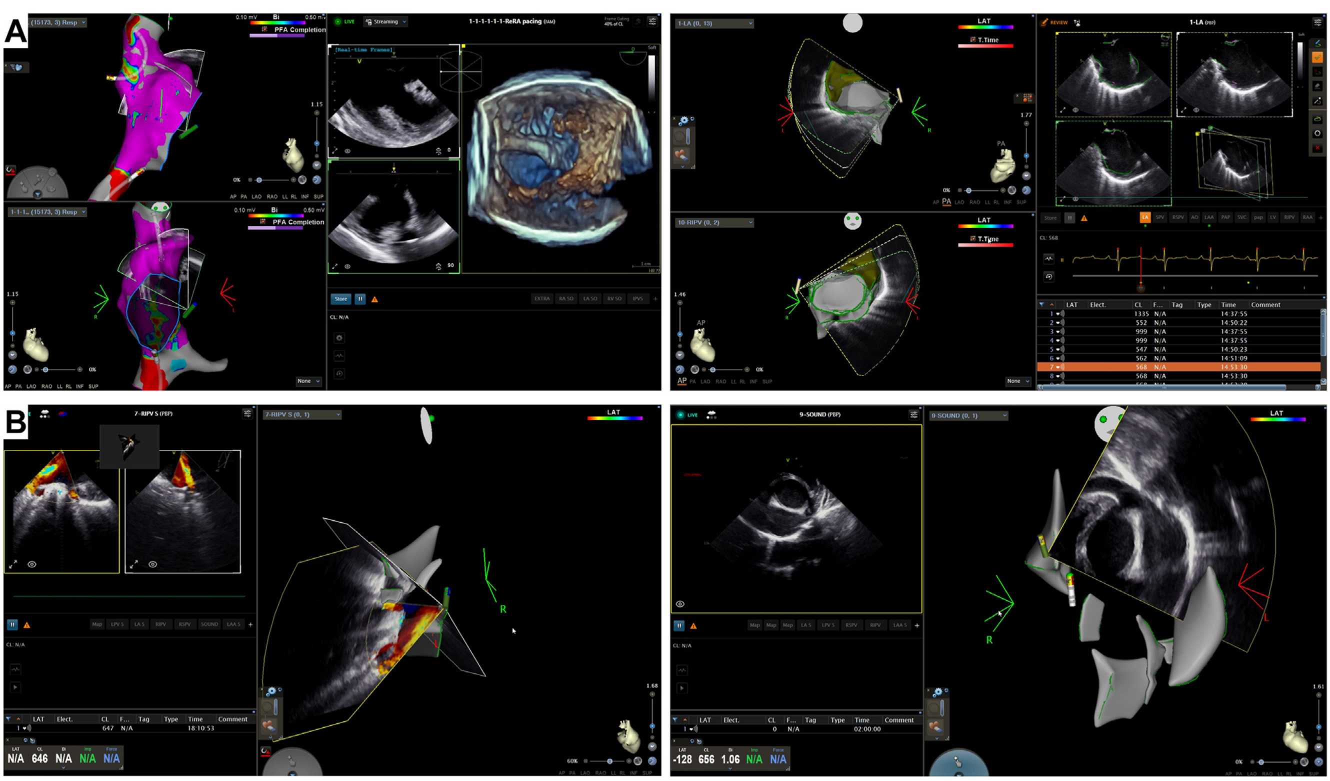

Figure 1 **A:** Right atrial map with 4-dimensional and biplane ultrasound image of the crista terminalis. **B:** Color Doppler flow of the left atrial veins (*left*) and ablation catheter tracking (*right*).

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Ethics Statement: Care and use of animals in this report were approved by the Institutional Animal Care & Use Committee and conformed to the Position of the American Heart Association on Research Animal Use and the guiding principles of the Declaration of Helsinki.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hroo.2023.11.013.

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