Navigated DENSE Strain Imaging for Post RF-Ablation Lesion Assessment in Swine Left Atria: A Comparison with Delayed Enhancement

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PURPOSE

Navigator-echo 3D Myocardial Delayed Enhancement (MDE) has demonstrated an ability to diagnose the completion of circumferential Radio-Frequency Ablation (RFA) at the Left-Atrial (LA)/Pulmonary-vein (PV) junction [1, 2]. Complete circumferential ablation reduces the likelihood for recurrence of Atrial Fibrillation following RFA, and its MRI confirmation is a strong incentive for MRI-guided Electro-physiology. The shortcomings of MDE are the required 30 min post-injection delay following Gadolinium (Gd) contrast injection, false-interpretation due to pre-existing fibrotic tissue, as well as safety questions surrounding the further ablation of regions from which the Gd has not entirely cleared. These factors complicate use of MDE as an intra-procedural ablation-monitoring tool. Ultrasound (ULS) Acoustic Radiation Force Imaging (ARFI) [3] is a possible alternative, utilizing an analysis of tissue displacement induced by a large acoustic force. We hypothesized that high-resolution DENSE strain imaging [4, 5] during atrial diastole would disclose changes in atrial and/or proximal pulmonary-vein (PV) motion following RFA, allowing non-contrast validation of the existence of circumferential PV isolation.

METHODS

Four intubated swine (HR=85±30 BPM) were imaged pre-RFA and one month post-RFA in a 1.5T scanner (GE Healthcare CV/I, HDx software release) using an 8-channel cardiac array. RFA ablations were induced only in the Right-Superior Pulmonary Vein (RSPV), with circumferential electrical isolation established immediately post-procedurally via atrial- voltage mapping using CarTo (Biosense-Webster, Diamond Bar, CA). The swine were scanned with 3D Navigated DENSE, and after Gd-injection (0.2 ml/kg) with 3D dual-cardiac-phase contrast-enhanced ECG-gated MR Angiography (MRA, 1.1x1.1x2.6mm resolution, 40 slice/20 sec) and with high-resolution navigated 3D MDE (1.2x1.2x2.6 mm resolution, 30 slice/5 min). High-resolution 2D DENSE scans with navigator-echo triggering (1.5x1.5x8 mm resolution, 4 mm/π displacement-encoding along both in-plane directions, 2-3 NEX, TR=3 RR (=1800-3300msec), 80 msec FSE readout, utilizing an IR pulse and phase-cycling for artifact suppression [ref 4], 5-7 min/slice acquisition) were executed with a late atrial-diastole "quiet" phase readout, in orientations: a. perpendicular to the atrial wall, b. along, and c. across multiple PV/LA junctions, covering both the ablated and non-ablated LA/PV junctions. Following the post-ablation imaging, CarTo was repeated to determine RSPV electrical isolation, followed by sacrifice and the dispatch of the atria for histological evaluation. For detailed visualization of the ablation lesions and the atrial anatomy, the diastolic 3D MRA images were segmented and overlaid with magnitude-thresholded 3D MDE images (Compare, GE Healthcare Advantage Windows 4.2, Waukesha, WI). DENSE data was post-processed using Dense Viewer (GE Healthcare ASL, Waukesha, WI), providing myocardial shortening and myocardial thickening strain maps.

RESULTS & CONCLUSION

Non-RFA associated 3D MDE signal enhancement was observed at the valves, at the distal PVs, on aortic and vena cava walls, and in the spine. This required manual segmentation to create the 3D MDE/3D MRA ablation injury models. In all four swine, gaps in the circumferential RSPV lesions were seen, 1 month post-RFA, using these models [Figure 1]. No 3DMDE enhancement was seen pre-RFA, or post-RFA, at the non-ablated LA/PV junctions. Reliable strain maps, at a spatial resolution of 2-3 vectors [8x8 displacement pixels] across the proximal PV wall, were produced with the DENSE acquisitions. Large changes in strain were seen in three out of the four pigs, in sectors [Figure 1 Right, Bottom] of the post-RFA ablated LA/PV junctions exhibiting hyper-intense MDE (Figure 1Right, Top]; 1. a reduction in strain magnitude from 20% to 5-10%, 2. a change in the strain vector patterns, reflecting a transition from directionally-synchronized (cohesive) motion to disorganized motion. It can also be seen [Figure 1 Right] that large-magnitude, organized-motion, strain is present in most of the un-enhanced 3D MDE sectors, suggesting an ability to resolve ablation gaps. The optimal orientation for viewing the strain changes was perpendicular to the PV orientation with slices obtained proximal and distal to the PV/LA junction. **Conclusion**: The navigated DENSE results suggest its utility as a non-contrast MRI tool for visualizing RFA damage, although at the lower spatial resolution than 3D MDE provides. Compared to ULS ARFI, the DENSE technique provides similar resolution, without the acoustic-shadows observed behind strong reflectors in ULS. Further study is required to establish normal strain values at the PV/LA junction at various cardiac phases, allowing optimization of strain imaging parameters. In addition, study on non-intubated humans will establish the technique's practical feasibility in this region of complex motion and thin walls.

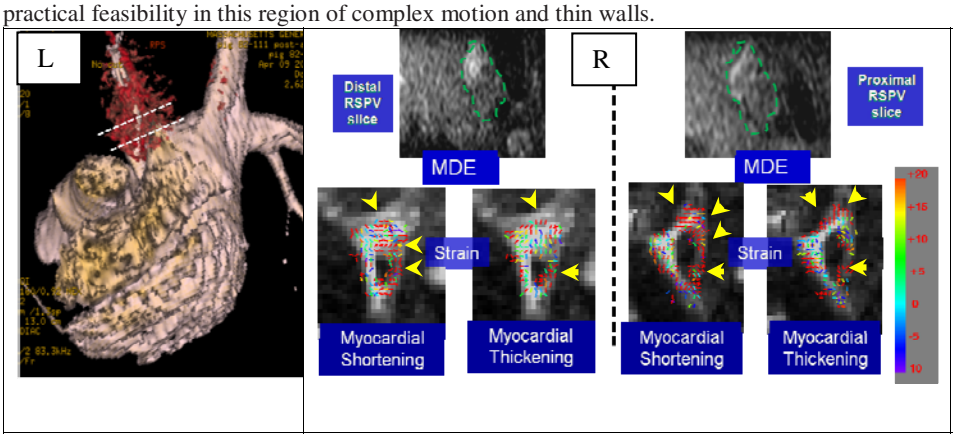

Figure 1: (L) 3D MRA model of ablated atrium/PV anatomy, showing ablated RSPV (red 3DMDE scar overlay). Note gaps in the ablation lesions. White doted lines show positions of the re-formatted 3DMDE and DENSE slices. (R). Comparison of reformatted 3DMDE (Top) with DENSE strain maps (Bottom) of the two slices shown on the Left. 3D MDE reformatted slices show ablation only in superior portion of veins (vein circumference traced in green). Both Myocardial Shortening and Thickening strain maps of each slice show high-strain (>20%), direction-organized, strain vectors only in non-ablated regions (ablation gaps, Yellow arrows).

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REFERENCES: [1] Peters DC, 2007, *Radiology*; 243 (3):690-5. [2] Reddy VY 2008, *J. Cardiovascular Electrophysiology*; 19 (4): 434-7. [3] Fahey BJ, 2004, *Ultrasound Med. Biol.*; 30 (3):321-8. [4] Aletras AH, 2001, *MRM*; 46(3):523- 534. [5] Fung MM, 2007 *ISMRM Proceedings*