Non-Contrast Enhanced Pulmonary Vein MRA with a Spatially Selective Inversion Preparation Sequence

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Introduction: Non-contrast enhanced pulmonary vein (PV) MRA is an alternative to contrast-enhanced PV imaging for assessment of PV anatomy prior to and after PV isolation as a treatment for atrial fibrillation (AF) (1,2). We propose a non-contrast enhanced three-dimensional (3D) free-breathing ECG-gated thin-slab spoiled gradient recalled echo (GRE) sequence with a slab-selective inversion for PV MRA.

Methods: A sagittal inversion slab, prescribed to cover the superior and inferior vena cava and the left atrium, was applied prior to data acquisition to suppress structures adjacent to the left atrium (LA) and PVs (Figure 1). Imaging was performed using a GRE sequence after an inversion time (TI), during which the inverted (and suppressed) vena cava blood flows into the right atrium, right ventricle and pulmonary artery while the PV blood was not affected. Consequently, the conspicuity of the PV and LA was improved. The proposed method does not require signal subtraction and the inversion slab is not parallel to the imaging slab. To optimize the TI and inversion slab thickness, the proposed imaging technique was performed on 5 healthy subjects using a series of inversion time (TI) and inversion slab thickness. The TIs and thickness corresponding to the best image quality and PV/LA conspicuity were chosen as the optimal TIs and thickness, respectively. The feasibility of the proposed method was further demonstrated in a cohort of 6 additional healthy subjects. Typical imaging parameters were: TR/TE/α=3/1.4/15˚, TI=500 ms, FOV=300×400×60 mm^3, isotropic spatial resolution 1.8×1.8×1.8mm^3 reconstructed to 0.9× 0.9×0.9 mm^3, 60mm inversion slab, ~550ms trigger delay, 50 views per segment, low-high view order, no parallel imaging . The slab-selective inversion pulse was an adiabatic pulse of the hyperbolic-secant shape. A 2D spiral echo beam navigator echo was positioned on the right hemi-diaphragm. A spectrally selective fat saturation pulse was applied. The contrast-to-noise ratios (CNR) between the PVs/LA and the right atrium (RA), ascending aorta and pulmonary artery were measured and compared with conventional non-contrast imaging without inversion. In addition, non-contrast PV MRA was performed on 9 AF patients using the optimized sequence. The maximum PV dimension was measured in the sagittal plane using a standard method (3). The PV measurements were compared with standard contrast-enhanced PV MRA using limits of agreement analysis, standard correlation and linear regression.

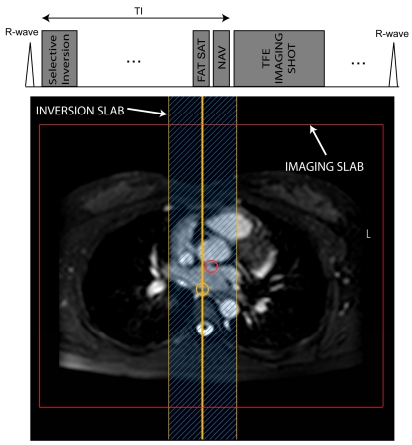

Figure 1: Sequence diagram (top) and illustration of imaging and inversion slabs (bottom). A slab-selective inversion pulse is applied after the R-wave trigger, which is followed by an inversion time (TI) before imaging.

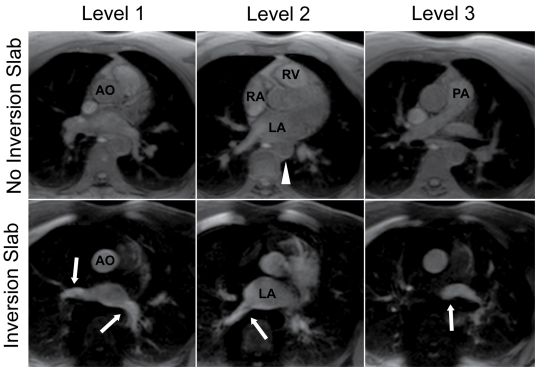

Figure 2: A comparison of images acquired on the same healthy subject using a 3D ECG-gated free-breathing GRE sequence without (top row) and with (bottom row) a sagittal selective inversion slab. The conspicuity and segmentation of the PVs (arrows) and LA was greatly improved.

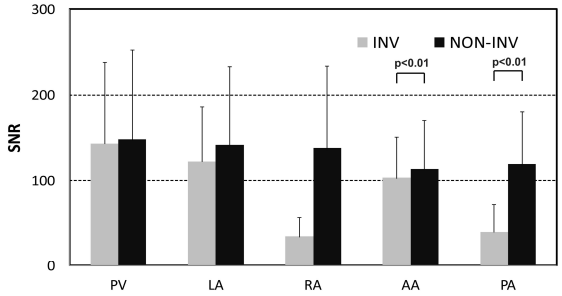

Figure 3: SNR measures of the proposed (INV) and conventional (NON-INV) techniques. The proposed technique suppresses RA and PA signal with minimal impact on PA and LA signal.

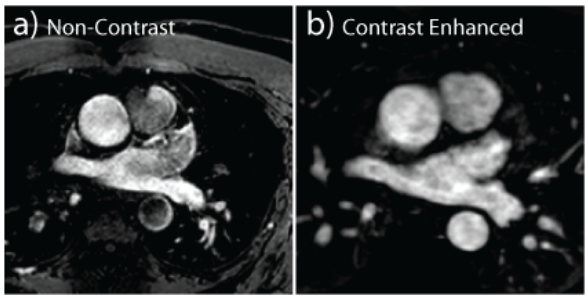

Figure 4: A comparison of images acquired on a AF patient with a) the proposed non-contrast technique and b) clinical breath-held contrast-enhanced PV MRA.

Results: The TI and the inversion slab thickness were optimized to be 500ms and 60mm, respectively. Compared to the conventional GRE sequence without inversion, the proposed technique greatly increased the visual conspicuity of the PVs and LA (Figure 2). The signal to noise ratios (SNR) of the PVs and the LA was similar with and without inversion ($p>0.3$), while the signals from the pulmonary artery and the right atrium were greatly reduced using the proposed technique (Figure 3). Figure 4 shows a comparison between non-contrast PV MRA and the clinical breath-held contrast-enhanced PV MRA. There was a difference of -0.1 +/- 2.2 mm between the PV size measurements of contrast-enhanced PV MRA and the proposed non-contrast technique, indicating no significant bias with limits of agreement of -4.5 to 4.3. The correlation was very good at 0.91 ($p<0.001$). Linear regression showed a close relationship between the two measurements with a slope of 0.93 ($p<0.001$).

Conclusions: The proposed non-contrast technique greatly enhances the conspicuity of the PVs and LA without significant loss of SNR and is promising for PV MRA of AF patients undergoing the PV isolation procedure. **Acknowledgements:** The authors acknowledge grant support from NIH R01EB008743-01A2, AHA SDG-0730339N, and Catalyst (Harvard Clinical and Translational Science Center). **References:** 1. Francois et al., Radiology 2009;250(3):932-939. 2. Krishnam et al., Invest Radiol 2009;44(8):447-453. 3. Hauser et al., J Cardiovasc Magn Reson 2004; 6(4):927-36