3D flow-insensitve coronary vessel wall imaging using phase sensitive inversion recovery

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Introduction: Double Inversion Recovery (DIR)-prepared TSE [1] is the current method to image coronary vessel wall. However, the acquisition window in each heartbeat with DIR-prepared TSE is limited due to the competing requirements between TI (blood signal nulling time), TD (period of minimal myocardial motion) [2]. A phase sensitive reconstruction method was proposed to overcome the problem of choosing the appropriate TI [2]. A major limitation of this technique is that the "black blood" effect of DIR still depends on the inflow of nulled blood, which makes this technique sensitive to slow or in-plane flow and less effective in patients with severe stenosis. In this work, we adopted the phase sensitive reconstruction method for 3D flow-insensitive coronary wall imaging and evaluated its feasibility in volunteers.

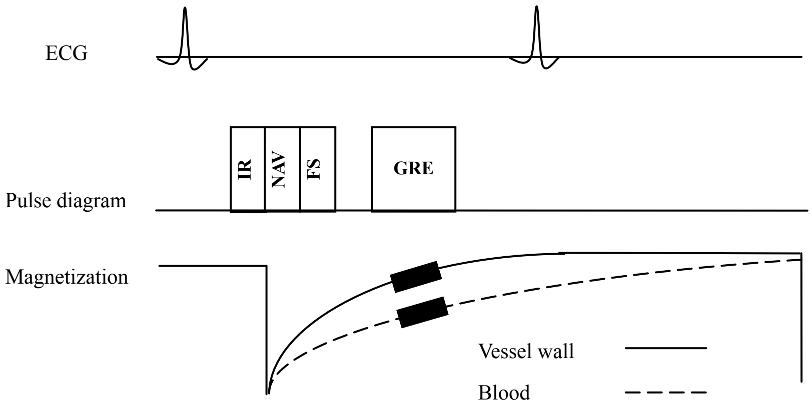

Fig. 1. Pulse sequence diagram and magnetization changes for coronary wall imaging. Navigator and fatsat pulses are played after a non-selective inversion pulse, followed by a 2D or 3D GRE acquisition module after a nominal TI.

Theory: In coronary artery wall imaging, blood has a longer T1 than the surrounding tissues (e.g., vessel wall, fat). After a non-selective inversion recovery (IR) preparation, blood will have the slowest recovery among these tissues, as shown in the magnetization recovery curve in Fig. 1. Because the inversion pulse is non-selective, image contrast in this technique is flow-insensitive. Phase sensitive inversion recovery (PSIR) technique [3] has been proposed to recover the true contrast between vessel wall and blood based on a reference scan in the following heartbeat. The problem with this method in coronary imaging is potential image misregistration between different heartbeats. We modified the reconstruction method proposed in [2] to perform phase sensitive reconstruction without a reference scan.

The complex image C(x,y) = M(x,y)P(x,y), in which M(x,y) and P(x,y) are the magnitude and phase images. The phase information can be expressed as $P(x,y) = e^{i\Phi(x,y)} = e^{iT(x,y)+iE(x,y)}$, in which $\Phi(x,y)$ is the actual acquired phase information and can be further decomposed into true phase T(x,y) plus phase error E(x,y). True phase of the image is determined by signal polarity. If acquisition is performed before vessel wall and blood longitudinal magnetizations recover to zero, T(x,y) is π. Phase error is mainly caused by field inhomogeneity and susceptibility variations and changes gradually, phase of the low resolution image is thus given by $\Phi_{low-resolution} = \pi + E(x,y)$. The true phase T(x,y) can then be calculated by $T(x,y) = \Phi(x,y) - \Phi_{low-resolution}(x,y) + \pi$. Finally the image that contains true contrast can be expressed as $I(x,y) = \mathbf{R}\{M(x,y) \times e^{iT(x,y)}\}$. Using this phase sensitive post processing, we can recover the true contrast between coronary vessel wall and lumen.

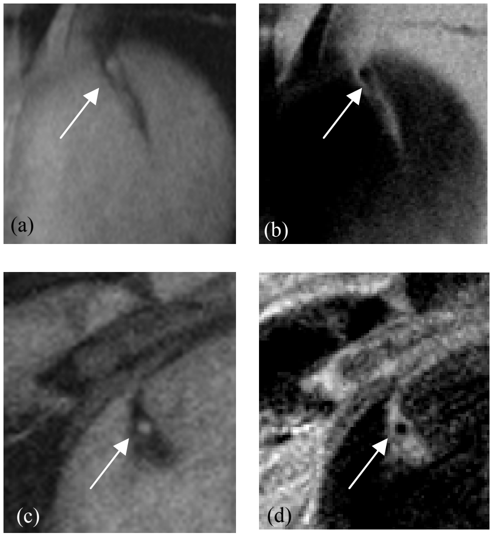

Fig. 2. (a,c) Cross-sectional view of coronaries with magnitude reconstruction only (arrows) in which blood is bright. (b,d) Phase-sensitive reconstruction results of the vessel wall containing signal polarity information in which blood is black.

Methods: Four healthy subjects (3 Male, 1 Female) on 3.0T (Trio, Siemens) using a 12-channel body coil array and spine coils. An ECG-triggered, navigator-gated, 3D segmented GRE sequence was used for acquisition. Parameters used were: TE = 2.34 ms, trigger pulse = 2, TI = 150 msec, flip angle = 15°, FOV = 300x300x16 mm^3, resolution = 0.9 x 0.9 x 4.0 mm^3, 6 slices, transversal view, 15 k-space lines per cardiac cycle, bandwidth of 410 Hz/pixel. Image processing was performed off-line using Matlab.

Results: Fig. 2 shows two examples of the cross-sectional view of the right coronary artery of two volunteers. Figs. 2 (a) and (c) are images with magnitude reconstruction only in which blood is bright, while (b) and (d) are PSIR post processing images that contain the signal polarity information and represent true contrast between vessel wall and lumen in which blood is black. Clear depiction of the vessel wall can be found. Fig. 3 is the MPR image formed from one volunteer to show the entire 24 mm coverage of right coronary artery vessel wall.

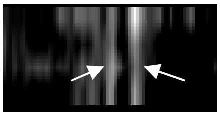

Fig. 3. MPR image of one volunteer that shows the 3D coverage of right coronary vessel wall (arrows).

Discussion and Conclusions: We developed a new 3D coronary vessel wall imaging technique using phase-sensitive inversion recovery. It is flow and TI-insensitive. Further optimization of the technique is required to optimize SNR and CNR.

References 1. Fayad ZA et al. Circulation 2000;102:506-510. 2. K. Z. Abd-Elmoniem, et al. ISMRM 2009, p17. 3. Peter K, et al. MRM 2002; 47: 372-383.