Large field-of-view submillimeter isotropic resolution bilateral peripheral vessel wall MRI using 3D fast spin echo with flow-insensitive blood suppression at 3 Tesla

T. D. Nguyen[1], K. Kawaji[2], P. Spincemaille[1], M. R. Prince[1], and Y. Wang[1,2]
[1]Radiology, Weill Cornell Medical College, New York, NY, United States, [2]Biomedical Engineering, Cornell University, Ithaca, NY, United States

INTRODUCTION

Peripheral vascular disease (PVD) is a leading cause of morbidity and mortality in the aging population. Black blood (BB) MRI can be used to characterize vessel wall and quantify atheresclerotic plaque burden. Flow-sensitive BB techniques such as double inversion recovery (DIR) (1,2) and spatial presaturation (3), as well as recently developed techniques including motion-sensitizing magnetization preparation (4) and fast spin echo imaging with long echo train (5), rely on blood flow and perform better in vessels with faster flow such as the aorta and the carotid arteries. In the lower extremeties where blood flow is slower, these techniques may suffer from residual blood artifacts mimicking plaque (6,7). Originally proposed for cardiac and carotid BB imaging (8), T2prep inversion recovery (T2IR) has been shown to provide flow-insensitive BB contrast for 2D peripheral vessel wall MRI at 1.5T at the cost of reduced wall SNR (9). This 2D technique additionally suffers from long scan times and limited volumetric coverage. The aim of this study is to achieve a considerable increase in T2IR BB imaging efficiency to obtain large field-of-view (FOV) bilateral peripheral coverage with sub-millimeter isotropic resolution in a reasonable scan time using SNR-efficient volumetric 3D data acquisition at higher 3T field strength.

METHODS

3D fast spin echo (FSE) sequence with T2IR preparation was implemented to utilize its robustness against increased B_0 inhomogeneity at 3T compared to 1.5T. Variable refocusing flip angles were used to prolong echo train length while reducing T2 blurring and the signal absorption rate (SAR) to stay within safety limits, a major concern for 3T imaging. To address the challenge of fat suppression due to increased B_0 and B_1 field inhomogeneities across a large imaging FOV, an adiabatic fat inversion pulse was used to null the fat signal (Fig.1).

T2IR timing parameters T2PREP time and TI (Fig.1) were optimized such that the wall signal is maximized while the blood signal is nulled at the beginning of the FSE readout. Numerical optimization was performed in Matlab with the following tissue relaxation values at 3T: $T1/T2_{blood}$ = 1900/280 ms and $T1/T2_{wall}$ = 1200/40 ms. Polynomial fitting was used to obtain empirical expressions for the optimized T2PREP time and TI as a function of TR and the FSE acquisition time (TFSE in Fig.1). These expressions were programmed into the 3D T2IR-FSE pulse sequence to enable automatic calculation of T2PREP time and TI.

Eight healthy subjects (29 ± 5 years) underwent peripheral vessel wall MRI at 3T (GE Signa HDxt 15.0). An 8-channel cardiac phased array was used for signal reception. The ungated FSE imaging parameters were: TR = 1200 ms, TE = 20 ms, coronal FOV = 28 cm, matrix = 384x384, echo spacing = 5.6 ms, echo train length = 64, number of slices = 100, T2PREP time = 90 ms, TI = 295 ms, TI_{FAT} = 50 ms, elliptical centric view order. To explore trade-off between SNR and voxel size, images were acquired twice with slice thickness of 1.4 mm (interpolated to 0.7 mm) and 0.7 mm and number of signal averages (NEX) of 2 and 1, respectively, for the same scan time of approximately 10 min. Muscle SNR, muscle-to-artery CNR, muscle-to-vein CNR, and muscle-to-fat CNR were measured to assess the image quality.

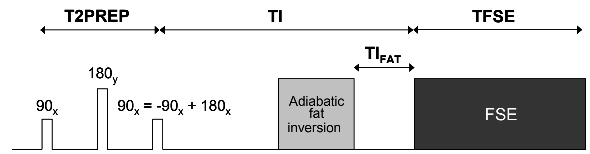

Fig.1. 3D T2IR-FSE sequence for peripheral vessel wall imaging at 3T. Note that all T2IR pulses are spatially non-selective and the -90_x tip-up of the T2prep sequence and the 180_x inversion pulse can be combined as shown.

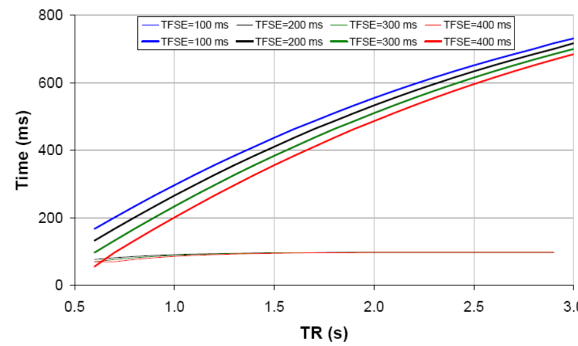

Fig.2. Optimized T2PREP time (thin line) and TI (bold line) as a function of TR and TFSE for T2IR-FSE vessel wall imaging at 3T.

RESULTS

Fig.2 shows the optimal T2IR timing parameters as a function of TR and TFSE. Note that T2PREP time is relatively constant and independent of TFSE (approximately 90-100 ms), while TI varies almost linearly with TR and slightly with TFSE. Imaging experiments were completed successfully in all subjects. Fig.3 shows an example of reformatted images of the distal superficial femoral and proximal popliteal arteries obtained with 0.7x0.7x0.7 mm^3 true and quasi (interpolated) isotropic resolution, demonstrating extended bilateral coverage, excellent arterial and venous blood suppression and fat suppression across the large FOV, and good vessel wall visualization. Quantitative SNR and CNR measurements are summarized in Table 1.

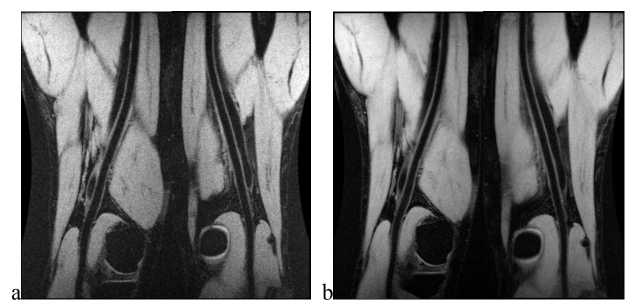

Fig.3. Reformatted peripheral vessel wall images obtained with a) true and b) quasi (interpolated) true isotropic resolution of 0.7x0.7x0.7 mm^3. Note the excellent blood and fat suppression across the large 28 cm FOV.

Table 1. SNR and CNR measurements of 3D T2IR-FSE (N=8).

	Muscle SNR	Muscle-to-artery CNR	Muscle-to-vein CNR	Muscle-to-fat CNR
True isotropic	24 ± 3	16 ± 4	15 ± 4	16 ± 3
Quasi-isotropic	48 ± 8	39 ± 7	38 ± 7	39 ± 7

DISCUSSION

Our preliminary data in healthy volunteers have demonstrated that T2IR 3DFSE imaging at 3T can provide effective blood suppression and 0.7 mm isotropic resolution of peripheral vessel wall over a long vessel length within a reasonable scan time. Quasi-isotropic resolution offers higher SNR at the cost of increased partial volume effect, and may be combined with parallel imaging to reduce scan time for a rapid overview of the vessels of interest. While providing lower SNR, true isotropic resolution allows reformatting of the acquired 3D volume into any desired image plane. Further improvement in SNR may be obtained with better receiver coils tailored for peripheral imaging. The developed sequence may be applied to the imaging of other vessel territories such as coronary and carotid arteries.

REFERENCES 1. Edelman et al. Radiology 1991;181:655. 2. Yarnykh et al. JMRI 2003;17:478. 3. Felmlee et al. Radiology 1987;164:559. 4. Koktzoglou et al. JCMR 2007;9:33. 5. Zhang et al. Invest Radiol 2009;44:619. 6. Wang et al. MRM 2007;58:973. 7. Liu et al. ISMRM 2008;3079. 8. Brown et al. ISMRM 2009;3843. 9. Nguyen et al. ISMRM 2009;608.