Black Blood Vessel Wall Imaging of the Lower Extremities with T2prep Inversion Recovery: A Feasibility Study

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INTRODUCTION

Black blood (BB) MRI of the vessel wall requires complete suppression of blood signal to delineate the vessel wall from the lumen. BB techniques including double inversion (DIR) (1,2), spatial presaturation of the upstream blood (SPSAT) (3), motion-sensitizing magnetization preparation (MSPREP) (4,5) have been demonstrated to perform well in elastic arteries (e.g., aorta, pulmonary, carotid) with fast blood flow. DIR and SPSAT rely on the inflow of nulled blood into the imaging volume, while MSPREP employs large gradients to dephase moving blood spins. In the peripheral arteries (e.g., in the lower extremities) where blood flow is substantially slower (6), these techniques may be less effective, leading to residual plaque-mimicking signals (DIR and SPSAT) (5) or reduced wall signal due to eddy current effects (MSPREP). T2 prepared inversion recovery (T2IR) has recently been shown to provide effective flow-insensitive blood suppression for cardiac and carotid BB imaging (7). The aim of this study is to optimize T2IR sequence parameters and investigate the feasiblity of T2IR fast spin echo (FSE) for lower extremity vessel wall imaging with DIR-FSE as a reference.

METHODS

T2IR integrates two classic MRI magnetization preparations, T2prep (8) and IR, to enhance the differentiation of tissues with similar T1 but different T2. For optimal T2IR BB imaging, sequence parameters TE and TI must be selected such that blood signal is nulled while wall signal is maximized at the start of the FSE readout (Fig.1). A closed form solution to the optimization problem exists when TR>>T1 (9). However, numerical optimization is required when TR is on the order of T1 as is the case for FSE acquisitions commonly utilized for vessel wall imaging. Accordingly, numerical optimization was performed in Matlab to determine TE and TI subject to the timing constraint TE+TI+TD=TR with the following tissue relaxation values at 1.5T: $T1/T2_{blood}$ = 1200/250 ms and $T1/T2_{wall}$ = 800/50 ms. Polynomial fitting was used to obtain empirical expressions for the optimal TE and TI as a function of TR. These expressions were then programmed into the T2IR-FSE pulse sequence to enable automatic calculation of TE and TI.

Imaging experiments were performed in ten healthy subjects (34 ± 12 years) at 1.5T (GE Signa HDx 14.0). A 7.5-cm circular surface coil was used for signal reception. Proximal femoral and popliteal artery walls were imaged with both 2D DIR-FSE and T2IR-FSE in randomized order. The FSE imaging parameters were identical for both techniques: FOV = 13 cm, matrix = 256x256, slice thickness = 4mm, echo spacing = 9 ms, echo train length = 4, multiple TE acquisition, number of signal averages = 3, TR = 2R-R. Vessel wall contours were traced by an experienced radiologist to determine wall area. Wall SNR and wall-to-lumen CNR were measured to compare image quality.

RESULTS

Fig.2 shows the optimal T2IR parameters as a function of TR. As TR increases, the optimal TE decreased very slowly, while the optimal TI increased approximately as a quadratic function. Fig.3 shows examples of excellent DIR-FSE and T2IR-FSE image quality demonstrating good qualitative agreement. In two subjects, prominent slow flow artifacts mimicking thickened wall were observed in DIR-FSE popliteal images, whereas T2IR-FSE images were artifact-free (Fig.4). Note that slow blood signal (T2~250 ms) persists on the image acquired at long effective TE (225 ms), while signals from vessel wall and surrounding muscles (T2~30-50 ms) have already decayed. Quantitative comparison between the two techniques is summarized in Table 1. Note that T2IR provided improved blood suppression at the cost of 28% and 52% lower SNR in the femoral and popliteal artery wall, respectively. Comparison between DIR-FSE and T2IR-FSE vessel wall areas revealed no statistical significance in both femoral (p=0.28) and popliteal (p=0.1) arteries.

DISCUSSION

Our preliminary data have demonstrated that high quality T2IR BB imaging of vessel wall in the lower extremities is feasible. T2IR can be readily incorporated into 3D imaging to provide effective blood suppression in a large imaging volume which would provide the additive benefit of improved wall SNR.

Table 1. Comparison of DIR-FSE and T2IR-FSE (N=10).

	SNR			CNR			Wall Area (mm^2)		
	T2IR	DIR	p	T2IR	DIR	p	T2IR	DIR	p
femoral	18 ± 6	25 ± 10	0.01	15 ± 6	21 ± 11	0.01	19.2 ± 5.4	20.0 ± 5.8	0.28
popliteal	31 ± 9	64 ± 18	<0.001	26 ± 9	55 ± 17	<0.001	12.7 ± 3.6	13.7 ± 4.8	0.1

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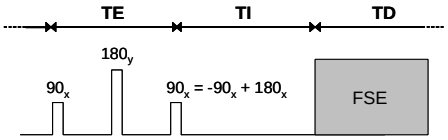

Fig.1. T2IR-FSE sequence schematic. Note that the -90_x tip-up of the T2prep sequence and the 180_x inversion pulse are combined.

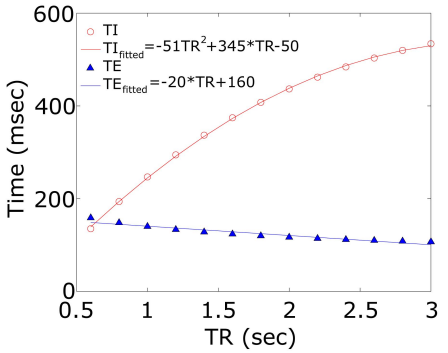

Fig.2. Optimal TE (triangle) and TI (circle) as a function of TR for T2IR-FSE vessel wall imaging at 1.5T. Best fit polynomial curves and corresponding equations are shown.

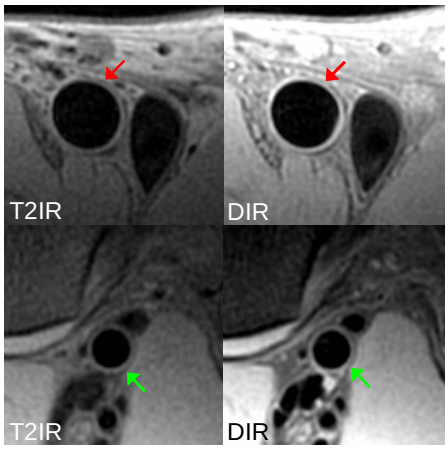

Fig.3. Concordant femoral (red arrows) and popliteal (green arrows) vessel wall images obtained with T2IR and DIR FSE.

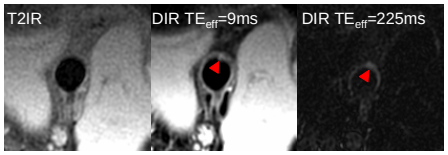

Fig.4. Slow flow artifacts can be seen at the popliteal wall-lumen border in the DIR image (red arrowhead) while blood is suppressed with T2IR.