High-Resolution 3D Isotropic Black-Blood Imaging with T2prep Inversion Recovery: Comparison between FSE and SSFP

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INTRODUCTION:

T2prep Inversion Recovery [1] (T2IR) is a hybrid magnetization preparation technique that combines two well-known preparations, T2prep and Inversion Recovery, to provide contrast between tissues with similar T1 but different T2 relaxation times. This unique property has been utilized in vessel wall imaging where the wall-lumen contrast needs to be maximized for accurate diagnosis. Recently, it was demonstrated [2,3] that T2IR can provide flow-insensitive global black-blood (BB) suppression and is therefore suited for peripheral vessel wall MRI where slow blood flow presents a major challenge for flow-sensitive BB techniques such as double inversion recovery and spatial saturation. However, this significant advantage comes at the expense of reduced wall signal-to-noise ratio (SNR), thus requiring prohibitively long scan times when 2D imaging is used [4]. The purpose of this study was to develop an SNR efficient 3D T2IR sequence for high-resolution volumetric imaging of the popliteal artery and to optimize the data acquisition by comparing fast spin echo (FSE) and balanced steady-state free precession (SSFP) sampling strategies at 1.5 Tesla.

METHODS:

Six healthy volunteers (mean age of 29±5 years) were scanned using an 8-channel transmit/receive knee coil. Figure 1 shows the schematic of our T2IR prepared vessel wall imaging sequence with an FSE or SSFP readout. Variable flip angle (VFA) acquisition with a prolonged echo train length [5] was used to improve SNR efficiency and reduce image blurring associated with T2 decay in FSE. SSFP was prepared with a 6 Kaiser Bessel flip angle ramp-up for efficient stabilization of the signal before readout. Optimal inversion time (TI) for effective blood suppression was determined by a rapid 2D scout scan acquiring images with varying TI. 3D coronal views of the superficial femoral and popliteal arteries were acquired on a GE HDxt 1.5T scanner with the following imaging parameters for both FSE and SSFP: matrix = 256x256x64, FOV=20cm, slice thickness = 0.8mm, receiver bandwidth = 62.5 kHz, number of excitations (NEX) = 2, number of echoes per segment = 64, time between subsequent T2IR preparations = 1500 ms, T2prep time = 100ms, spectrally selective fat saturation, centric view order. Other imaging parameters were as follows: for SSFP: TR = 3.9 ms, TE = 1.5ms, flip angle = 60°; and for FSE: TE_{eff} = 14.5 ms, echo spacing = 5.5 ms, variable flip angle refocusing pulses with minimum flip angle of 50°. Scan time was approximately 12 minutes for each scan. 2D phase contrast MRI was also performed to measure blood velocity and flow rate in the popliteal artery. Tissue SNR and tissue-to-lumen contrast-to-noise-ratio (CNR) was obtained using region-of-interest analysis.

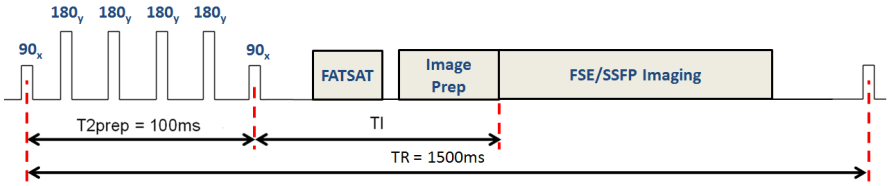

Figure 1. Schematic of T2IR prepared imaging sequence. T2IR preparation consists of a $+90_x$ tipdown pulse, followed by refocusing 180 pulses, and a combined -90_x tipup and 180x inversion pulse. T2prep and TI times can be varied to provide optimal black blood contrast for wall imaging. A spectrally selective fat saturation and appropriate SSFP magnetization preparation are played out during TI immediately before imaging.

RESULTS:

Figure 2 shows the reformatted view of T2IR-FSE and T2IR-SSFP vessel wall images, with T2IR-SSFP providing higher muscle SNR and tissue-to-lumen CNR than that of T2IR-FSE by 26% and 37%, respectively (Table 1). 3D imaging at 0.8mm isotropic resolution allowed image volume reformatting to generate axial views (Figure 2, bottom), of the vessel walls. Inflow of unsuppressed blood was observed in the femoral artery in T2IR-SSFP images near the edge of the transmit coil sensitivity profile, whereas T2IR-FSE images consistently provided global blood suppression. PC flow measurements yielded a mean blood flow of 89 ± 50 mL/min, and a peak blood velocity of 31 ± 11 cm/s.

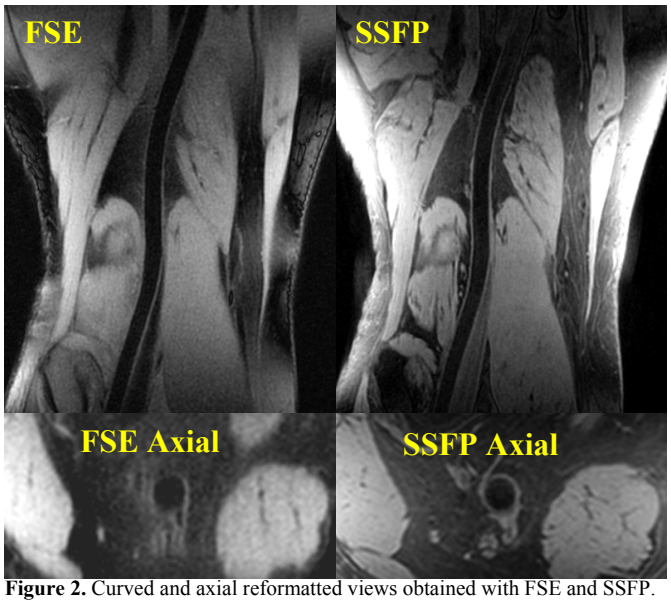

Figure 2. Curved and axial reformatted views obtained with FSE and SSFP.

Table 1 Summary of SNR and CNR measurements (n=6).

	FSE	SSFP	p
Muscle SNR	35±9	44±19	< 0.01
Muscle-to-Lumen* CNR	27±10	37±17	< 0.01

* Lumen measurements were made at the popliteal artery.

DISCUSSION:

Both T2IR-SSFP and T2IR-FSE techniques provided excellent blood suppression and isotropic submillimeter resolution with sufficiently high SNR, with T2IR-SSFP yielding better SNR and CNR measurements. As SSFP can maintain a signal in steady state for data acquisition, its SNR efficiency is high. While the use of VFA in FSE can improve SNR efficiency by creating a pseudo steady-state during the readout, the signal yield is eventually exhausted, resulting in relatively lower SNR efficiency compared to SSFP. However, in contrast to an inherently bright blood T2IR-SSFP sequence, T2IR-FSE is inherently a black blood sequence and therefore may provide better global blood suppression and is less affected by the inflow of fresh blood when a localized volumetric coil is used.

References: [1] Brittain et al. MRM 1997; 38:591-603. [2] Liu et al. Proc. ISMRM 2008; pp3079. [3] Brown et al. Proc. ISMRM 2009; pp3844. [4] Nguyen et al. Proc. ISMRM 2009; pp607. [5] Hennig et al. MRM 2003; 49:527-535.