Implementation of Time Efficient Double Inversion FSE technique on a 3.0T system

S-E. Kim[1], E-K. Jeong[1], J. R. Hadley[1], D. L. Parker[1]

[1]Department of Radiology, University of Utah, Salt Lake City, UT, United States

INTRODUCTION: Recent publications show that multiple contrast images of carotid artery obtained by black blood fast spin echo (FSE) techniques are helpful for plaque component identification[1-2]. Due to the nonselective inversion pulse in double inversion techniques, black blood images are usually acquired sequentially, resulting in long imaging times. To improve the time efficiency previously our group proposed multiple slice approaches[3-4] for multiple contrast black blood imaging. Compared to 1.5T, black blood FSE images obtained by double inversion preparation at 3.0T have been shown to provide improved signal to noise ratio (SNR) for human heart applications[5]. However, due to the application of multiple inversion and refocusing pulses the specific absorption rate (SAR) issue results in a limitation to imaging parameters such as repetition time or flip angle of refocusing pulse for time efficient multiple slice imaging at 3.0T system. In this paper, a time efficient double inversion FSE technique was implemented on a 3.0T MRI system. In this implementation, three-slice-interleaved acquisition was used for (PD) and T2 weighted black blood image acquisition. To reduce the SAR, a reduced flip angle was used for the refocusing pulses. For T1 weighted image acquisition, with reduced TR, two-slice-interleaving was used with hyperechoes for the refocusing pulses of the echo-train.

METHODS: The two- (Fig. 1A) and three- (Fig. 1B) slice-interleaved black blood sequences were created as modified versions of the double inversion preparation FSE technique. The modified version of double inversion consists of one non-selective adiabatic hyperbolic secant pulse of duration 10240 μs followed by three (slice A, slice B, slice C) or two (slice A, slice B) spatially selective adiabatic pulses for PD/T2 imaging or T1 imaging, respectively. After the inversion time (TI) a T1, PD or T2 image from one location (slice A) was obtained by the FSE or hyperecho technique. Slice A, B, and C were spatially separated to avoid cross talk between slices and acquisition was alternated for the other slice(s) (slice B or Slice C) during repetition time (TR). In this sequence each slice has the same TR, but the effective TR for each inversion pulse is TR/3 (PD/T2) or TR/2 (T1).

All volunteer studies were performed on a 3.0 T Siemens Trio system (Siemens Medical Solutions, Erlangen, Germany) with our home built four element bilateral phased array carotid coil. Carotid arteries of a normal subject centered around the bifurcation apex were scanned with three-interleaved FSE for T2 and PD imaging with our modified version of the double inversion preparation sequence. Other scan parameters were: TR=2s, TI=350 ms, TE=8.7ms (PD) or 65.4 ms (T2), 256x256 acquisition matrix (512x512 matrix after interpolation), 13 cm FOV, 2 mm slice thickness, and 9 echo train length. The total scan time for 12 slices was about 4 min. To reduce TR to 700ms for T1 imaging, the two interleaved hyperecho technique was used with TI=150 ms. The scan time for 12 locations of T1 images was 2 min 57sec with that same resolution as that used for PD and T2 images. To compare SNR and CNR between interleaved hyperecho and the sequential FSE technique the sequential FSE images were obtained with the same parameters as those of the hyperecho T1 images. The scan time for 12 sequential images was 5 min 12 sec.

RESULTS: Figure 2 demonstrates T1, T2, PD carotid artery images from a normal volunteer. Each column shows different contrast images from identical locations. T1 images from Row (A) using the sequential FSE demonstrate similar SNR and tissue contrast as the two-interleaved hyperecho T1 images shown in Row (B). Corresponding T2 and PD images obtained with the three-interleaved FSE technique from the same location are shown in Rows (C) and (D). All images show good blood suppression and decent SNR with just single averaging.

DISCUSSION: Black blood imaging at 3.0T may provide improved information for evaluation of size and morphology of plaque in the carotid artery. Our modified version of the double inversion preparation sequence could improve imaging time efficiency by a factor of 2 or more on carotid artery applications on a 3.0T system. The hyperecho technique, in which 60° refocusing pulses are applied, can reduce SAR of these sequences in high field systems. For more accurate or clinically useful vessel wall imaging, further work to improve fat saturation (fat saturation was not used for these images), more evaluation of the dependency of hyperecho signal intensity on TE or TR should be performed.

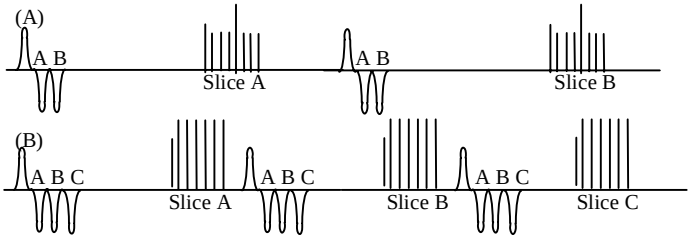

Figure 1 The pulse diagram for the two-slice-interleaved (A) and three-slice-interleaved versions of double inversion preparation black blood FSE. SAR is reduced by using hyerechoes for signal refocusing.

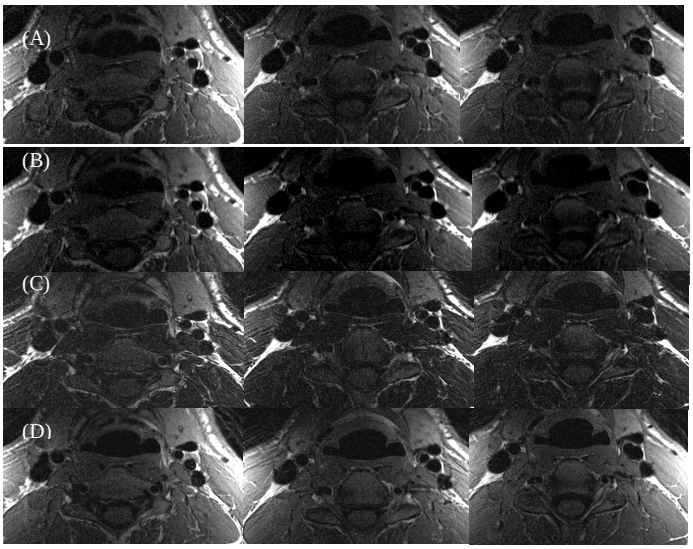

Figure 2: Examples of black blood multiple contrast images from a normal carotid artery. (A) T1 images with sequential FSE. (B) T1images with two-interleaved hyperecho. T2 (C) and PD (D) images with the three-interleaved FSE technique.

ACNOWLEDGEMENT: Supported by HL 48223, HL 53696, Siemens Medical Solutions.

REFERENCES:

1. Luo Y, et al. Accuracy and uniqueness of three in vivo measurements of atherosclerotic carotid plaque morphology with black blood MRI. MRM 2003; **50**:75.
2. Cai J, et.al. Classification of human carotid atherosclerotic lesions in-vivo multi-contrast magnetic resonance imaging. Circulation 2002; **106**:1368.
3. Parker DL, Goodrich K, Masiker M, Tsuruda J, et.al. Improved efficiency in double-inversion fast spin-echo imaging. MRM 2002; **47**:101..
4. Kim SE, Jeong EK, Parker DL, et al, Triple contrast technique for black blood imaging with double inversion preparation, MRM (accepted).
5.Greenman RL, et al, Double inversion black blood imaging of the human heart: A comparison between 1.5T and 3.0T. JMRI 2003; **17**:648.
6. Hennig J, and Scheffler K. Herechoes. MRM 2001; **46**:6.