Time Efficient Carotid Artery Imaging using TSE with Reduced Field of View and Interleaved Double Inversion at 3 Tesla

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INTRODUCTION:

Multiple contrast carotid artery images obtained with turbo/fast spin echo (TSE/FSE) techniques with double inversion recovery (DIR) magnetization preparation are very helpful for plaque component identification[1-2]. Due to the nonselective inversion pulse used in the preparation, these DIR images are usually acquired sequentially, resulting in long scan times. To improve the time efficiency of carotid studies, interleaved multiple slice/multiple contrast DIR acquisition techniques have been developed.[3]. Techniques that limit or reduce the field of view (rFOV) [4] in the phase encoding direction, require fewer phase encodings and thereby further reduce scan times. rFOV techniques combined with double inversion preparation has been adopted for 3D black blood carotid imaging[5] to achieve limited volume imaging of human carotid and reduced scan time. The standard rFOV preparation, which includes a phase encoding selective RF pulse is only applicable for non-interleaved single slice/slab imaging because the out-of-slice magnetization is saturated by the rFOV preparation. In this paper, we present a time efficient rFOV double inversion TSE technique that allows 2D interleaved multi-slice. We apply this technique on a 3T MRI scanner where image SNR is typically very high, but imaging times can be increased because of heating (SAR) restrictions.

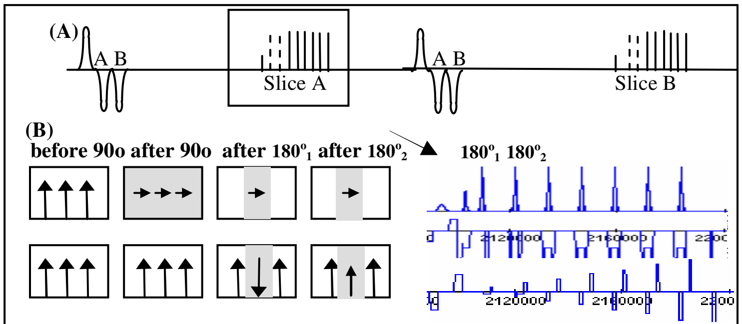

Figure 1. (A) Modified version of double inversion preparation with rFOV – TSE pulse sequence. (B) The 1st row shows the magnetization evolution while imaging slice A from an interleaved acquisition of 2 slices (A,B) using rFOV-TSE sequence and the magnetization evolution of non-imaged slice (slice B) is shown at 2nd row.

METHODS:

Figure 1 shows an example of two slice interleaved TSE sequence with DIR preparation and rFOV during acquisition. The interleaved double inversion consists of one non-selective and two slice-selective (slice A and slice B) adiabatic hyperbolic secant pulses of duration 10240 μs. After time delay, TI, data for one spatial location (slice A) is acquired by the rFOV-TSE technique. Slices A and B are widely separated in space to avoid cross talk between them. Data acquisition is alternated between the slices every other repetition time (TR). Compared to the standard rFOV preparation, in our rFOV preparation the first two180° refocusing RF pulses of the TSE sequence are applied with slice-selection gradients in the phase encoding (PE) direction. The first PE selective 180° pulse ($180^o{}_1$) is used to refocus the spins in the limited region of the imaged slice and inverts the spins in the out-of slice region. The second PE selective refocusing pulse ($180^o{}_2$) returns the spins in the non-imaged slices toward the original state, aligned along Bo. As shown Fig. 1b, the magnetization external to the imaged slice experiences two 180° pulses separated by a short time period (echo spacing time). As a result, the magnetization is only slightly reduced by our rFOV preparation allowing interleaved multi-slice data acquisition.

All studies were performed on a 3T Siemens Trio MRI scanner (Siemens Medical Solutions, Erlangen, Germany) with our home built four element bilateral phased array carotid coil. Carotid arteries of a normal subject were scanned using our interleaved double inversion preparation TSE sequence with and without rFOV preparation. Typical scan parameters were: TR=800 ms, TE=8.7 ms, TI=150 ms, 256x256 imaging matrix,13 cm FOV, 2 mm slice thickness, and echo train length of 9. Total scan time for 12 slices data acquisition was approximately 4 min. A fat saturation RF pulse was applied to eliminate the fat signal. For rFOV images, asymmetric FOV (130x40 mm) with a 256 x 78 imaging matrix was used. Other parameters remained the same, and the scan time was reduced to 1 min 20 sec for acquisition of 12 slices.

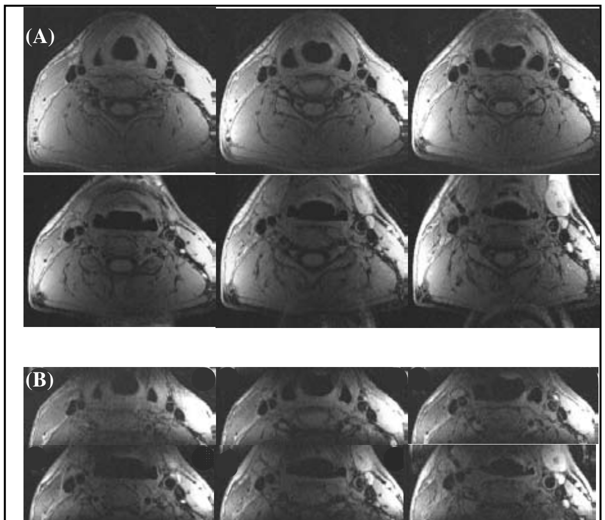

Figure 2. The black blood carotid images using time efficient double inversion preparation TSE sequence without (A) and with (B) rFOV technique. The in-plane resolution for both technique was 0.5x0.5 mm.

RESULTS:

Figure 2A demonstrates carotid artery images acquired using interleaved DIR preparation TSE from a normal volunteer. Each image in Fig. 2A shows different locations near the bifurcation area. Corresponding rFOV images obtained with the rFOV-TSE technique from the same spatial locations are shown in Fig 2B. All images in Fig. 2 demonstrate good blood signal suppression and reasonable SNR with just single averaging.

DISCUSSION:

Black blood (DIR) imaging on a 3 Tesla system may provide improved information for evaluation of size and morphology of carotid artery plaque. In comparison with conventional DIR imaging techniques, our interleaved DIR rFOV-TSE technique can improve acquisition efficiency and reduce the total time required for imaging the carotid artery by a factor of 6. The incorporation of parallel imaging into the time efficient DIR-rFOV-TSE technique can further decrease the time required for image acquisition. These techniques are important at 3T where the high SNR is sufficient to allow implementation of such time reduction techniques.

ACNOWLEDGEMENTS: Supported by NIH grants R01 HL 48223 and HL 53696, Siemens Medical Solutions.

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