Improved motion-sensitized driven equilibrium (iMSDE) blood-suppression sequence for atherosclerosis plaque imaging at 3T

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Introduction

Multi-contrast black blood (BB) imaging is important for atherosclerosis diagnosis and accurate plaque component characterization [1, 2]. To achieve sufficient blood suppression, flow-dephasing black-blood imaging techniques, such as the motion-sensitization driven equilibrium (MSDE) sequence, has been recently utilized for carotid artery vessel wall imaging [3, 4]. Although the blood suppression capability of the MSDE sequence has been shown to be superior to other black blood techniques, considerable amount of signal loss was observed if stronger and longer motion sensitization gradients were used. This signal loss could be caused by local B1 and B_0 imperfection. In this abstract, we proposed a novel improved MSDE (iMSDE) scheme that is less sensitive to the system B1 and B_0 inhomogeneities and is therefore able to provide better image quality without sacrificing blood suppression efficiency.

Methods

Sequence The major change introduced in the original MSDE sequence is the addition of a 2^{nd} 180 degree refocusing pulse (Fig. 1). The group of 4 RF pulses was constructed in an MLEV-4 scheme, and both 180 degree pulses were composite pulses that comprise 90y-180x-90y pulses. If the total duration between the two 90 degree pulses was defined as TE_{prep}, the gaps between pulses were $TE_{prep}/4$, $TE_{prep}/2$ and $TE_{prep}/4$, respectively. Four motion sensitization gradients with alternative polarities were fitted into the MLEV-4 setup as Fig.1 shows. The scheme of placing sensitization gradients was proposed to maximize the first gradient moment (m_1) within a fixed TE_{prep}. The first gradient moment is the parameter that controls the flow suppression capability of the prepulse [4].

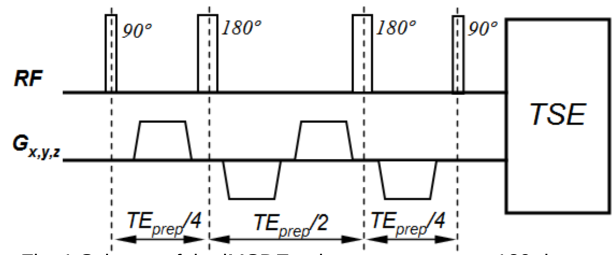

Fig. 1 Scheme of the iMSDE pulse sequence; two 180 degree refocusing pulses were utilized.

Simulations A Bloch equation based computer program was utilized to evaluate the signal sensitivity to the B1and B_0 field non-uniformities, for both MSDE and iMSDE sequences. The program was custom-coded in MATLAB (Mathworks, Natick, MA). In this simulation, relative B1 (rB1) was used to quantify the B1 inhomogeneity, and frequency shift was used to quantify B_0 inhomogeneity. T1 and T2 of 1000 and 200ms, respectively, were used for simulation; TE_{prep} is 8ms. The ratio of magnetization in z direction before and after the prepulse was calculated for different rB1 and ΔB_0 values. Therefore, the closer the result to 1, the smaller signal loss will occur for a specific rB1 and ΔB_0 combination.

Experiments All images were acquired using a 3T clinical scanner (Philips Achieva, R2.1.1, Best, Netherland). MSDE and iMSDE sequences were applied at the same location. To assure a fair comparison, both prepulses always utilized same gradient strength (20mT/m) and m_1.Two sets of m_1 were used to demonstrate the flow suppression capability, low m_1=512mTms^2/m and high m_1=1581mTms^2/m. For low m_1 case: MSDE gradient duration: 3.75ms, iMSDE gradient duration: 1.7ms. For high m_1 case: MSDE gradient duration 7.5ms, iMSDE gradient duration: 3.57ms. Both sequences used same TSE acquisition sequence: TR/TE: 4000/9ms, FOV 160*120mm, matrix: 256*192, slice thickness: 2mm, NEX 1. In the phantom study, a water bottle was scanned to compare the SNR level. A healthy volunteer was also scanned to test the flow suppression capability of both sequences.

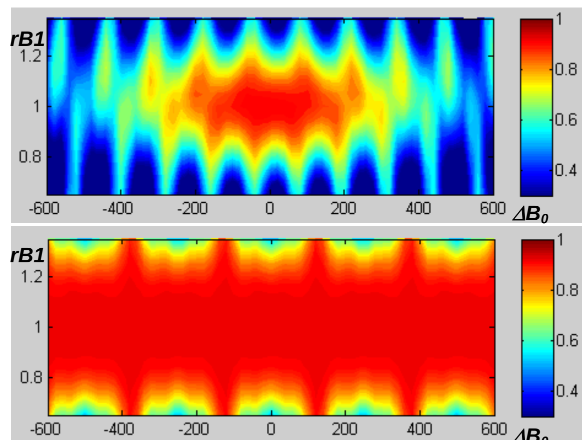

Fig. 2 Simulation results used to estimate the signal level for both MSDE and iMSDE sequences at different rB1 and ΔB_0 values; TE_{prep}=8ms. The improved MSDE sequence (lower panel) can generally provide higher signal levels than the traditional MSDE sequence (upper panel).

Results

Simulations The signal intensity simulation results are shown in Fig. 2. The iMSDE sequence can generally retain higher signal level than the MSDE sequence for almost all rB1 and ΔB_0 combinations. Signal levels in the traditional MSDE sequence drops significantly when rB1 and ΔB_0 values drift from the ideal situations. While those of the iMSDE sequence are very well retained, even when situations are not ideal.

Experimental study In the high m_1 condition, the average signal level of the iMSDE sequence is much higher than that from the MSDE sequence. This has been confirmed by both phantom tests (Fig. 3) and in vivo images (Fig. 4 (b)(c)). In the in vivo comparison, the flow artifact that cannot be suppressed in low m_1 setup appears effectively suppressed in high m_1 setup (arrow). However, when m_1 is high, MSDE image presents considerable signal loss (b), while iMSDE sequence retains signal very well (c).

Conclusions The new design of the MSDE sequence considerably improves the immunity of the method to B1 and B0 inhomogeneities, and therefore may extend MSDE applications in high-field imaging.

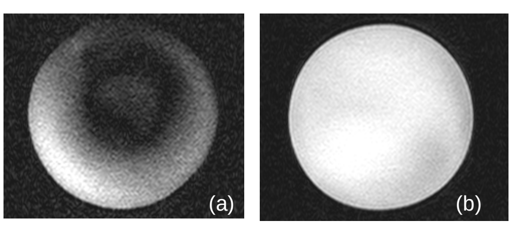

Fig. 3 Comparison between the signal loss of MSDE (a) and iMSDE (b) sequences at high m_1 condition – m_1=1581 mTms^2/m

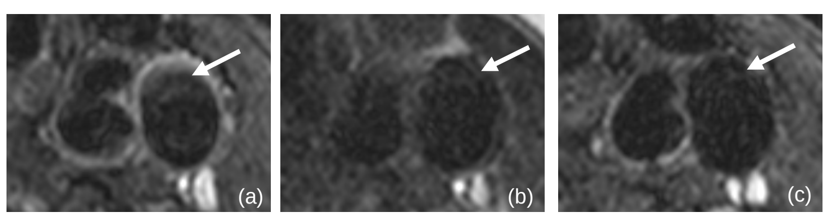

Fig. 4 In vivo carotid imaging comparison between techniques: (a) is MSDE with low m_1=512mTms^2/m; (b) is MSDE with high m_1=1581mTms^2/m; (c) is iMSDE with high m_1=1581mTms^2/m. Significant signal drop in MSDE when m_1 is high, but not in iMSDE.

References:

1. Saam T et al., *Radiology*, 2007 244:64-77
2. Fayad ZA et al., *Ann N Y Acad Sci*, 2000, 902:173-86
3. Koktzoglou I et al., *JCMR*, 2007, 9:33-42.
4. Wang J et al., *MRM*, 2007, 58:973-981