Fluid Suppression for MRI Screening by Dual Echo Subtraction

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Introduction: Magnetic resonance imaging (MRI) has been increasingly used for whole-body screening of tumor metastasis (1). The prolonged T_2 and restricted diffusion of the tumors render short-tau inversion recovery (STIR) (2) and EPI based diffusion weighted imaging (DW-EPI) (3) the preferred methods for screening. However, both these sequences are SNR limited and require multiple signal averages, increasing the total scan time. Further, DW-EPI images are subject to distortion when used with larger fields-of-view (FOV).

Recently, a contrast-edited RARE method was proposed as an alternative to DW-EPI for screening, where confounding tissue signals were suppressed using various preparation modules (4). While this technique produced images with increased tumor conspicuity compared to standard RARE, the inversion pulse used to null fluid increases the overall scan time and fails to suppress fluids with intermediate T_1s of 2-3s. To overcome this limitation, we have developed an alternative technique to suppress fluid and tissue with very long T_2 without a significant increase in the total scan time. The technique was evaluated on normal volunteers and on an experimental tumor model in the mouse.

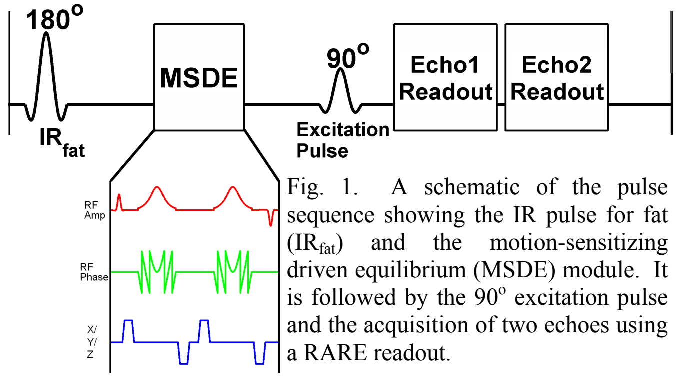

Fig. 1. A schematic of the pulse sequence showing the IR pulse for fat (IR_{fat}) and the motion-sensitizing driven equilibrium (MSDE) module. It is followed by the 90° excitation pulse and the acquisition of two echoes using a RARE readout.

Methods: The schematic of the pulse sequence is shown in fig. 1. A single-shot half-Fourier RARE sequence was modified: 1) to include a spectrally selective adiabatic inversion pulse to suppress fat (IR_{fat}), 2) followed by a motion-sensitizing driven equilibrium (MSDE) to suppress flowing blood and 3) to acquire two echoes – one at a shorter echo time (TE) and the other at a longer TE, following the same excitation. The hypothesis was that the normal tissues with shorter T_2 and metastatic lesions with moderately prolonged T_2 appear only on the shorter TE image, while tissues with very long T_2, such as fluid filled cysts and fluid in bowel, will appear on both short and long TE images. Thus, a difference image suppresses the signal from the long T_2 tissue. For initial feasibility studies, the sequence was tested on normal subjects (with IRB approval) on a 1.5 T scanner using a 192×128 resolution and TEs of 60 ms and 230 ms. Additionally, the sequence was also evaluated on a mouse renal cell carcinoma model and compared against DW-EPI with b=0 and 600 s/mm^2 using STIR (5) fat suppression on a 3T scanner.

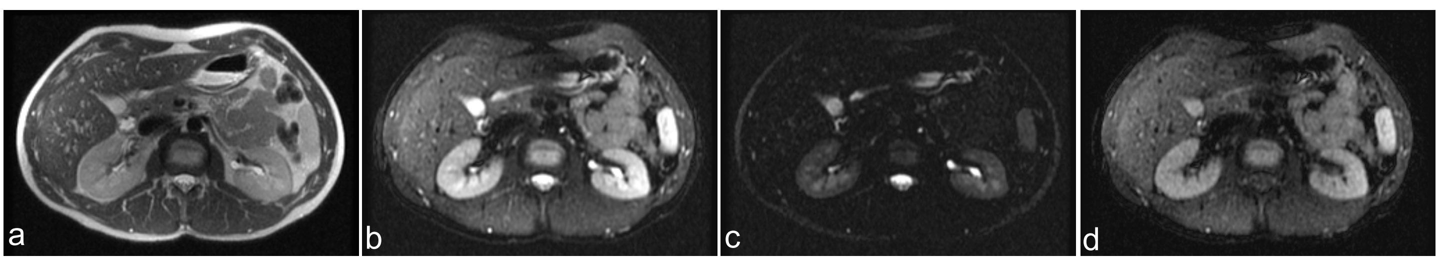

Fig. 2. Volunteer images are shown from standard single-shot half-Fourier RARE with no fat suppression (a), shorter TE with fat and blood vessels suppressed (b) and the corresponding longer TE image (c). The difference image (d) was generated by subtracting the longer TE image (c) from the shorter TE image (b), reducing the signal intensity from long T_2 fluid such as CSF around the spine and urine.

Results: On a normal volunteer (fig. 2), compared to standard single-shot half-Fourier RARE with no fat suppression (a), IR_{fat} produced uniform fat suppression and MSDE suppressed blood signal from major vessels in both shorter TE (b) and longer TE (c) images. Additionally, the longer TE image shows signal only from the long T_2 tissue. The difference image, generated by subtracting longer TE image from the shorter TE image, has significantly reduced signal intensity from all of the confounding tissues. In a mouse tumor model (fig. 3), the subtracted image (c) highlights the signal intensity of the tumor while suppressing the various background tissues compared to standard single-shot half-Fourier RARE image (d). Severe distortion of the tumor can be noticed in DW-EPI images with b=0 s/mm^2 (e) and b=600 s/mm^2 (f) due to tumor/air interface.

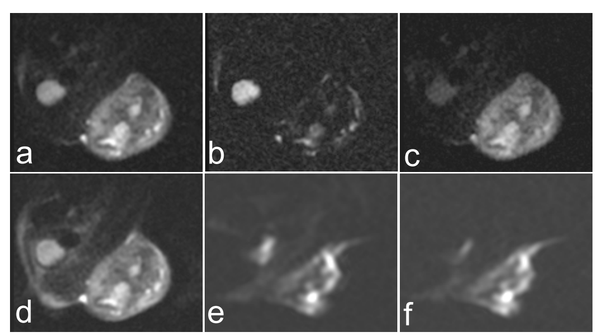

Fig. 3. Images of a mouse tumor on the hind leg.

Discussion: The preliminary results in normal subjects and a mouse tumor model show that the proposed method is capable of producing high SNR images using a single average while suppressing the undesired signals from fat, fluid and blood vessels. The process of subtraction to acquire the final image reduces the SNR; however, it significantly minimizes the image mis-registration issues due to motion since both the echoes were acquired following same excitation. The feasibility of the technique for improved conspicuity of the lesions needs to be validated in patients. This technique could provide an alternative to whole-body DW-EPI, which has been shown to detect malignant tumors with similar accuracy to ^{18}F-FDG PET/CT (6).

Reference: 1) Lauenstein et. al. JMRI 24: 489-498 (2006); 2) Hargaden et. al. AJR 180: 247-252 (2003); 3) Koh et. al. AJR 188: 1622-1635 (2007); 4) Madhuranthakam et. al. ISMRM 18: 4703 (2010) 5) Takahara et. al. Radiation Medicine 22: 275-282 (2004); 6) Komori et. al. Ann Nucl Med 21: 209-215 (2007).