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# SE_MC sequence improves image quality of carotid arteries and atherosclerotic plaques

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## Introduction

Double-Inversion-Recovery (DIR) FSE is the standard MRI sequence used to acquire blood suppressed 2D high-resolution T1, PD and T2-weighted images for atherosclerotic plaque characterization in the carotid arteries.

## Purpose

FSE images suffer from blurring because of non-uniform T2-weighting of k-space [Constable, Gore.MRM.1992.28(1):9-24], which is stronger on small structures with short T2 times, such as carotid arteries. To avoid this, we propose to generate T1-PD-T2-weighted images using Spin-Echo Multi-Contrast (SE_MC) sequence. FSE and SE_MC are both CPMG multi-echo sequences; however FSE acquires different lines of the same k-space at different TEs, whereas SE_MC samples multiple k-spaces (with constant TE) at different TEs.

## Methods

The image formation process for SE and FSE sequences was simulated in MATLAB (MathWorks) applying the same parameters and k-space acquisition strategy used in-vivo (TE = 14 ms, ETL = 9). An average carotid artery (lumen-diameter = 7 mm, wall-thickness = 1 mm, T2 = 40 ms) was simulated by linear combination of Bessel functions in k-space. In the in-vivo study, 6 normal volunteers (6 m, 30 ± 5 years) and 12 atherosclerotic patients (10 m, 74 ± 9 years) were imaged at 3 T (TIM Trio, Siemens Medical Solutions) using surface coils (FOV = 150 × 150 mm, matrix = 320 × 320, slice = 2 mm). The ECG-gated DIR-FSE pulse sequence (ETL = 9) was used to acquire T1w (TE = 14 ms, TR = 1RR, Tacq <60s) PDw (TE = 14 ms, TR = 2RR, Tacq <120s) and T2w (TE = 89 ms, TR = 2RR, Tacq <120s) images. The ECG-gated parallel DIR-SE_MC sequence (partial k-space = 5/8, SENSE-iPat = 2) acquired 7 contrast images (TE = 25.8-103.2 ms) for TR = 1RR (Tacq <120s) and TR = 2RR (Tacq <240s). T2 maps were estimated by non-linear regression and synthetic T1-PD-T2-weighted images were generated at TE = 14 ms (T1w-PDw) and TE = 89 ms (T2w).

## Results

In normal volunteers, FSE images show a significant blurring along the phase-encoding direction, consistent with the simulated images. T1w and PDw are more affected by blurring than T2w images because low spatial frequencies (along the phase-encoding direction) are sampled at short TEs. Horizontal and vertical image profiles highlight the difference between the phase-encoding and the frequency-encoding directions for both FSE and simulated images. SE_MC images do not suffer from blurring, thus arterial wall boundaries are sharper and better contrasted. Details of plaque morphology and composition are more clearly visible in SE_MC images, Figure 1.

## Conclusion

This study suggests that replacing FSE with SE_MC in vascular MRI protocols could benefit the segmentation of vessel walls and atherosclerotic plaques with the only disadvantage of a slightly longer acquisition time. Phantom experiments will be soon performed to quantify the error on vessel wall measurements caused by FSE blurring.

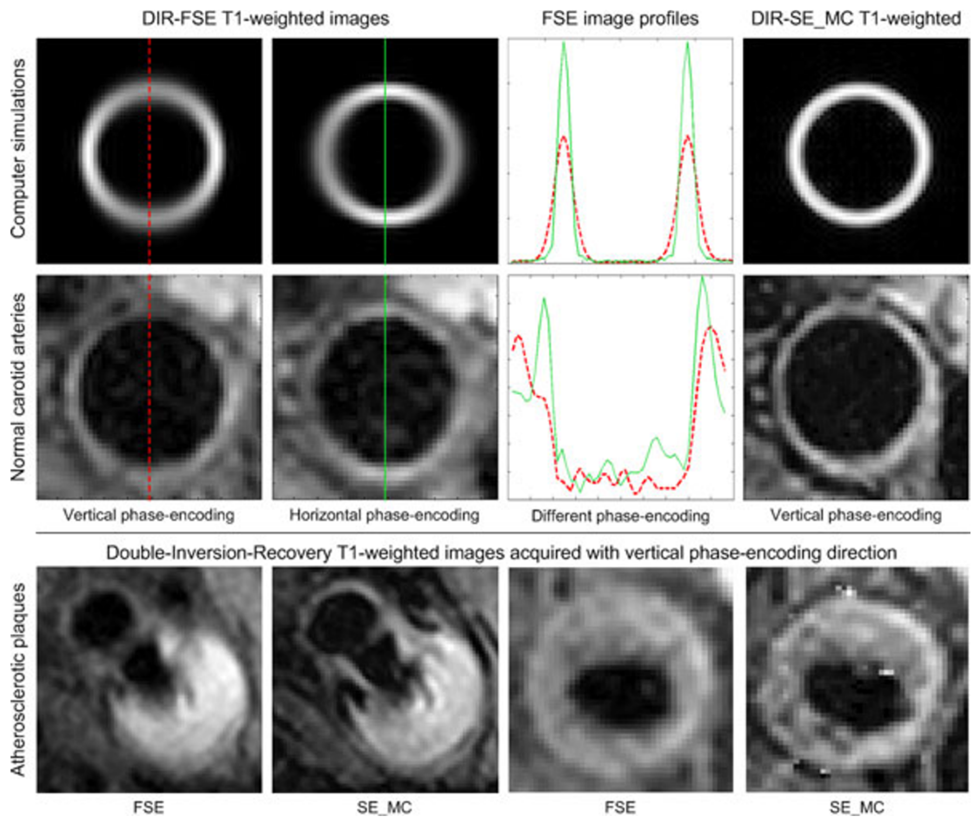


**Figure 1**
**Comparison between FSE and SE_MC dark-blood carotid images in computer simulations, normal volunteers and atherosclerotic patients**.