Magic Sandwich Echo Imaging of the Human Knee Joint

A. J. Wheaton[1,2], R. R. Regatte[1], M. T. Corbo[1], A. Borthakur[1], R. Reddy[1]

[1]Dept. of Radiology, University of Pennsylvania, Philadelphia, PA, United States, [2]Dept. of Bioengineering, University of Pennsylvania, Philadelphia, PA, United States

Introduction: Highly organized tissues generally contain oriented components such as collagen fibers that produce non-averaged dipolar interactions between bulk water protons which result in a substantial shortening of the T_2. The magic sandwich echo (MSE) technique [1] has been previously applied to capture these short T_2 components in both ex vivo [2] and in vivo tissues [3]. The MSE imaging sequence (Fig. 1) contains a 'magic sandwich' consisting of two $\pi/2$ pulses surrounding a rotary echo of spin-lock (SL) pulses which takes the place of a conventional 180˚ refocusing pulse. In this format, the MSE sequence refocuses the signal from both short and long T_2 spins, but not off-resonance components. The purpose of this work was to measure the increase in signal in musculoskeletal tissue as well as the intrinsic fat suppression in MSE images obtained on a standard clinical scanner.

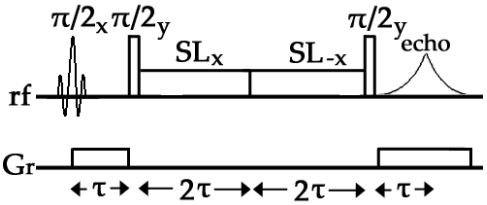

Figure 1: MSE pulse sequence schematic.

Methods: Axial MSE images of the knee joints of 4 healthy volunteers were acquired on a Siemens 1.5 T Sonata scanner using the MSE sequence with the parameters: FOV = 15 cm x 15 cm, slice thickness = 3 mm, matrix = 256 x 256, 2 averages, TR = 2 s, and spin-lock amplitude (γB_1) = 250 Hz. The time-to-echo (TE) of the MSE sequence was 15 ms. For comparison, T_2-weighted images with identical experimental parameters were acquired using a standard SE sequence with and without fat suppression using a chemical shift selective pulse. In addition, to illustrate the intrinsic fat suppression of the MSE sequence, images were acquired of bottles of agarose and lipid solution. For all image sets, the percentage increase in signal between the MSE and SE images was calculated as [(MSE(x,y) – SE(x,y)) / SE(x,y)] to create a percentage difference map.

Results: The MSE images acquired on the clinical scanner contained a localized zero-peak artifact. The artifact is a result of the refocusing of non-phase-encoded spins by the magic sandwich (Fig 2). The signal from those tissues containing T_2-shortening structural components, like cartilage and muscle, was increased by ~35% which is in agreement with previously reported data [2]. In particular, the signal near the subchondral junction in the patellar cartilage where dense bundles of collagen fibers insert into the bone was increased by nearly 100% indicating an area of strong dipolar coupling. The phenomenon of intrinsic fat suppression is illustrated in Fig. 3. The fat signal was suppressed in the MSE images by an average of 74 ± 8% which is comparable to the fat suppression provided by the chemical shift selective pulse of 91± 5%.

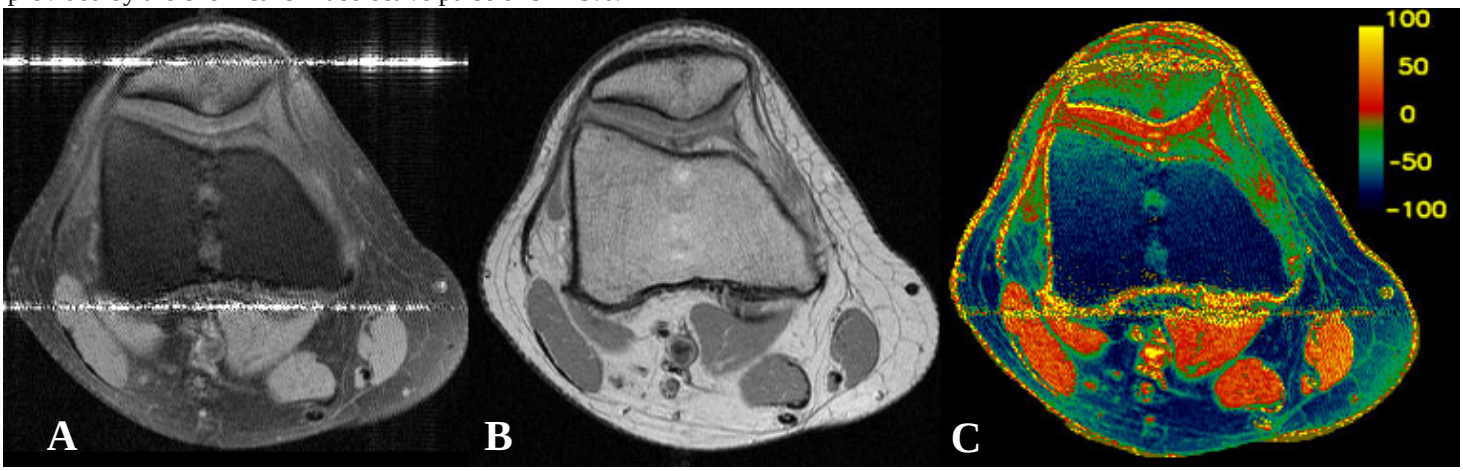

Figure 2: A) MSE, B) SE, and C) percent difference map of human knee joint. The barscale represents the percentage difference between the MSE and SE image.

Discussion: This work demonstrates the feasibility of acquiring in vivo MSE images of human tissue on a standard clinical scanner. The MSE images highlight regions of oriented tissue which can be used to delineate specific information about dipolar effects. The sequence couples an increase in tissue signal (+35% in cartilage and muscle) with an intrinsic reduction in signal from fat of ~75%. The increased tissue-fat contrast can be exploited for improved identification of tissues of interest without the need for a chemical shift selective pulse. The MSE derived data can be used to study tissue structure and composition as well as pathology.

Support from NIH grants RR02305 and R01-AR45404, and the Whitaker Foundation.

References: **1.** Rhim WK, Pines A, Waugh JS. Phys Rev B 1971. 3;684-96. **2.** Grenier D, Pascui O, and Briguet A. JMR 2000. 147; 353-6. **3.** Grenier D, Wachsmuth LK, Carjaval L, Majumbar S. Proc ISMRM 2001. 9;528.

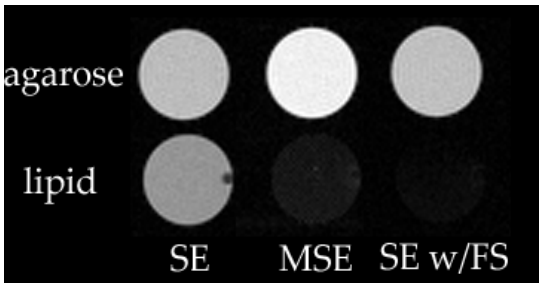

Figure 3: Fat suppression by MSE v. SE with fat sat (FS). The signal of agarose is increased by 28% in the MSE image compared to standard SE. The lipid signal is decreased by 84% in MSE compared to 94% by FS.