Improved Fat-Suppression for Unspoiled GRASS Imaging of the Knee Using Multi-Peak IDEAL Chemical Shift Fat-Water Separation

R. Kijowski[1], C. D. Hines[2], H. Yu[3], and S. B. Reeder[1,2]
[1]Radiology, University of Wisconsin, Madison, Wisconsin, United States, [2]Medical Physics, University of Wisconsin, Madison, Wisconsin, United States, [3]GE Healthcare, Applied Science Laboratory, Menlo Park, California, United States

Objective: Iterative Decomposition of water and fat with Echo Asymmetry and Least squares estimation (IDEAL) is a chemical shift based fat-water separation method that can be combined with unspoiled Gradient Recalled-echo Acquired in the Steady-State (GRASS) technique to produce high resolution, fat-suppressed images of the knee with bright synovial fluid (1). IDEAL-GRASS has high diagnostic performance for detecting surgically confirmed cartilage lesions within the knee joint but is currently limited by suboptimal fat-water separation which makes it difficult to assess the exact depth of cartilage lesions and to detect post-traumatic and degenerative subchondral bone marrow edema (2). Previously investigated versions of IDEAL-GRASS have modeled fat as a single resonance peak. Since fat consists of multiple chemically distinct moieties which give rise to at least 6 resonance peaks, single-peak IDEAL fat-water separation fails to suppress up to 15% of signal arising from fat protons (3). An advantage of IDEAL is that its signal model can be easily modified to include multiple fat peaks, so long as the resonance frequencies and relative amplitudes of these peaks are known *a priori* (4, 5). The purpose of this study was to evaluate and quantify improvements in the quality of fat-suppression for GRASS imaging of the knee using more accurate multi-peak spectral modeling of fat and IDEAL fat-water separation.

Methods: An IDEAL-GRASS sequence (TR=10.1ms, TE=4.4, 5.4, and 6.1 ms, FOV=15cm, matrix=384x224, slice thickness=1mm, bandwidth=41.5kHz, signal average=1, and scan time=5min) was performed on the knees of 10 asymptomatic volunteers using a 3.0T scanner (Sigma Excite HDx, GE Healthcare, Waukesha, Wisconsin) and an 8-channel channel extremity coil. The IDEAL-GRASS images were reconstructed using a single-peak method and an investigational version of a multi-peak method that more accurately models the NMR spectrum of fat. SNR and CNR were measured within cartilage, synovial fluid, and bone marrow for the single-peak and multi-peak IDEAL-GRASS images. Paired student t-tests were used to compare SNR and CNR values.

Results: Multi-peak IDEAL-GRASS had significantly greater ($p<0.001$) suppression of bone marrow signal than single-peak IDEAL-GRASS (Figure 1). Multi-peak IDEAL-GRASS had on average 24% greater suppression of signal within bone marrow when compared to single-peak IDEAL-GRASS. Multi-peak IDEAL-GRASS also had significantly greater ($p<0.001$) CNR between cartilage and bone marrow than single-peak IDEAL-GRASS (Figure 2). On multi-peak IDEAL-GRASS images, fat was noticeably darker which resulted in improved contrast between cartilage and bone marrow (Figure 3).

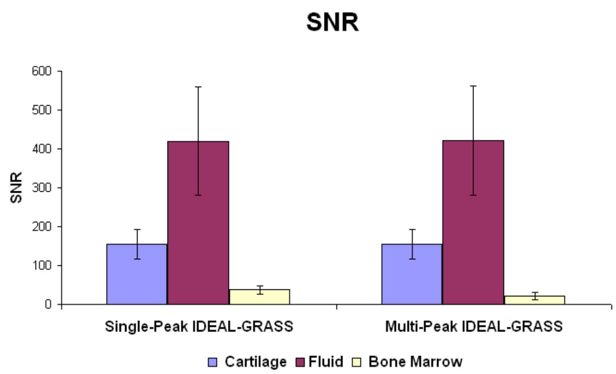

Figure 1: SNR comparison between single-peak and multi-peak IDEAL-GRASS.

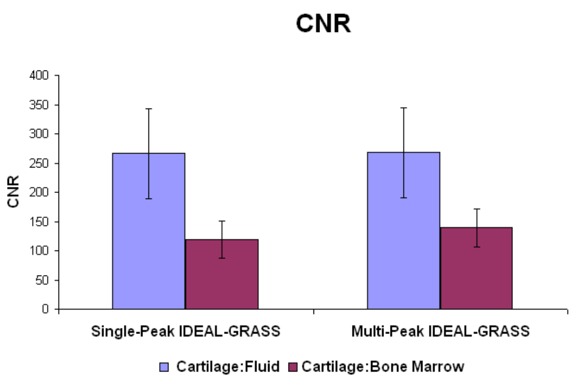

Figure 2: CNR comparison between single-peak and multi-peak IDEAL-GRASS.

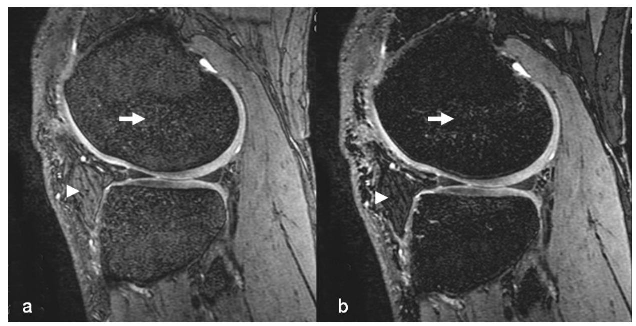

Figure 3: Sagittal single-peak IDEAL-GRASS (a) and multi-peak IDEAL-GRASS (b) images of the knee in an asymptomatic volunteer. Note the darker fat signal within bone marrow (arrow) and subcutaneous fat (arrowhead) on the multi-peak IDEAL-GRASS image.

Conclusions: Multi-peak IDEAL fat-water separation provides improved fat-suppression for unspoiled GRASS imaging of the knee when compared to single-peak IDEAL. We are currently investigating newly developed magnitude correction methods to reduce the effects of eddy currents which may provide even greater fat-suppression for GRASS imaging. Future studies are needed to determine whether the decreased bone marrow signal on multi-peak IDEAL-GRASS images improves the characterization of cartilage lesions and the detection of post-traumatic and degenerative subchondral bone marrow edema.

References: 1) Kijowski, et al. Magn Reson Med. 28:167, 2008. 2) Kijowski, et al. Radiology. In Press. 3) Brix, et al. Magn Reson Imaging. 11:977, 1993. 3) Yu, et al. Mag Reson Med. 60:1122, 2008. 5) Middleton, et al. ISMRM 2009, p. 4331.