Cartilage Morphology at 1.5T: Comparison of 3D FS-SPGR and IDEAL SPGR Imaging

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Introduction: Three-dimensional (3D) MRI is useful to measure articular cartilage thickness and volumes. Historically, the primary sequence for measuring cartilage morphology has been 3D spoiled gradient echo (3D-SPGR) with chemical fat saturation [1, 2]. Other methods of reducing signal from lipid include spectrally selective excitation and Dixon methods. Dixon methods are appealing because the TR can be much shorter than fat-suppressed methods where the frequency selective pulse can take up to one-half the TR. We have recently developed a Dixon technique for use with 3D-SPGR called Iterative Dixon water-fat separation with Echo Asymmetry and Least-squares (IDEAL) [3]. We compared cartilage SNR, fat-saturation and image quality of IDEAL SPGR with fat saturated SPGR (FS-SPGR) in 10 knees of normal volunteers at 1.5T.

Methods: Ten knees (seven volunteers) were imaged using a GE Signa TwinSpeed 1.5T MRI scanner and a quadrature extremity coil. FS-SPGR was done with TR/TE 18.5/4 ms, an 11-degree flip angle and two acquisitions for a scan time of 10:47. IDEAL SPGR was done with TR of 13.5 ms, three TE increments of 4.4, 6.0, and 7.5 ms, a 9-degree flip angle, and a scan time of 10:46. All scans were 512x416 matrix, 16 cm field-of-view, 2 mm section thickness, 42 sections, and acquisition bandwidth of $\pm$62.5 kHz. Flip angles were optimized for maximum cartilage SNR, based on the Ernst angle and cartilage T1 of 1000ms [4, 5]. Dixon images were reconstructed on-line using the IDEAL method [3].

SNR was measured from regions of interest in the trochlear cartilage. SNR values were compared using a student t-test. Image quality and uniformity of fat saturation was graded on a scale of 0-3 (0 = poor, 1 = fair, 2 = good, 3 = excellent). Two experienced radiologists scored the images by consensus. Image quality and fat saturation results were compared using a Wilcoxon signed rank test.

Results: IDEAL SPGR produced images with higher cartilage SNR than FS-SPGR (Figure 1), which was statistically significant ($p < .001$). Image quality was graded good to excellent for both IDEAL SPGR (2.9) and FS-SPGR (2.5), with the IDEAL SPGR being significantly better ($p < .05$). The fat-saturation score for IDEAL SPGR (3.0) was significantly better ($p < .05$) than FS-SPGR (2.6). All images had excellent depiction of cartilage (Figure 2) while the IDEAL SPGR images produced water, fat, and combined images.

Conclusion: IDEAL SPGR provides a fast, SNR efficient method for examining articular cartilage at 1.5T. Because of the lack of a chemically selective radiofrequency pulse, IDEAL SPGR was done in the same scan time with one more signal average. Fat saturation pulses can take up a large percentage of the TR in FS-SPGR, and can decrease water signal. FS-SPGR is also sensitive to both B0 and B1 inhomogeneity, while IDEAL SPGR is not. The ability to provide recombined fat and water images that correct for chemical shift may also allow assessment of subchondral bone thickness [5]. IDEAL SPGR can also be accelerated using parallel imaging and partial k-space acquisition. Our results indicate that IDEAL SPGR is a highly promising technique for imaging articular cartilage thickness and volume at 1.5T.

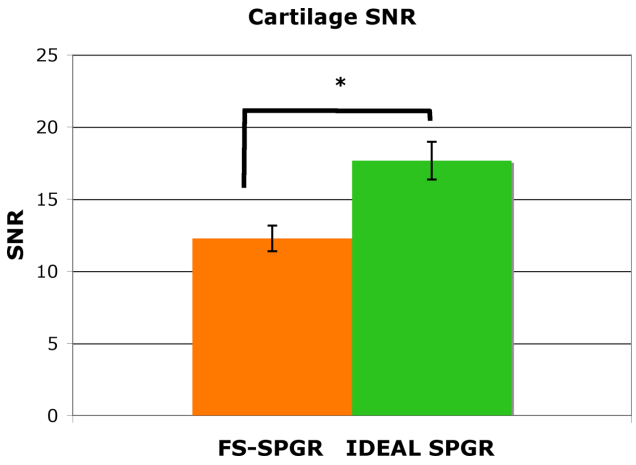

Figure 1: IDEAL SPGR has significantly (*$p < .001$) higher overall cartilage SNR than FS-SPGR.

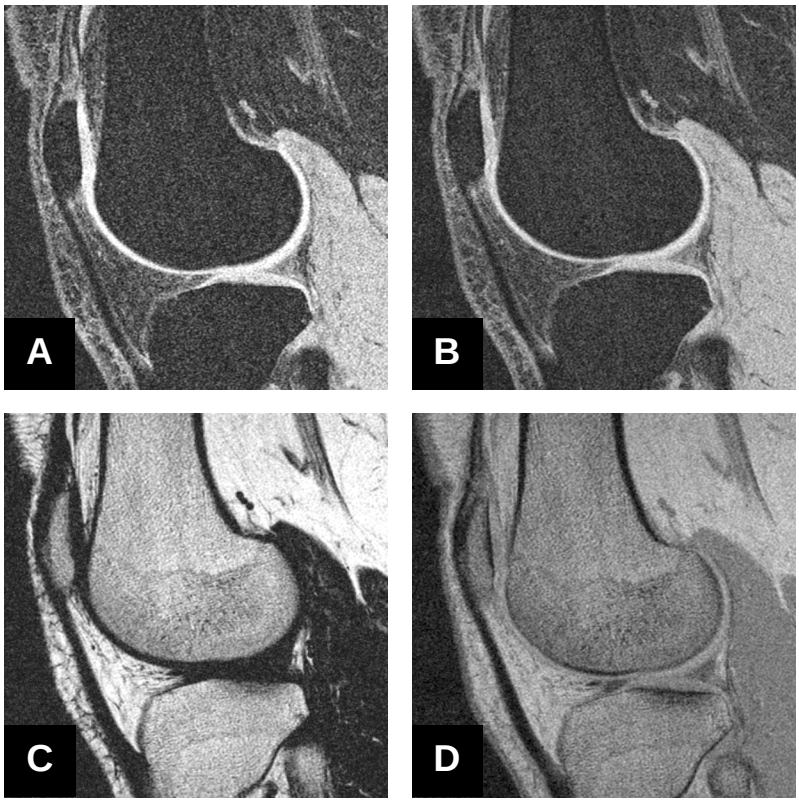

Figure 2: Images from a healthy volunteer. A) FS-SPGR. B) IDEAL SPGR water image. C) IDEAL SPGR fat image. D) IDEAL SPGR combined image. IDEAL SPGR was graded significantly higher in image quality and fat saturation ($p < .05$).

References

[1] Disler, et al. Am J Roentgrnol. 163:887-92 (1994).

[2] Eckstein, et al. Osteoarthritis Cartilage. 10:941-21 (2002).

[3] Reeder, et al. Magn Res Med. 51(1): 35-45 (2004).

[4] Gold, etl al. Am J Roentgenol. 183:343-351 (2004).

[5] Reeder, et al. Magn Res Med. 32(5): 612-21 (1994).

[6] McGibbon, et al. MAGMA 16:1-9 (2003).

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