Rapid Cartilage Morphology at 3.0T: Comparison of FS-SPGR, FS-SSFP, and "Dixon" SSFP 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 fat saturation [1, 2]. Recently, there has been a great deal of interest in using sequences based on steady-state free precession (SSFP) for fast, high SNR imaging of cartilage. Two options for 3D fat-suppressed cartilage imaging with SSFP are intermittent fat saturation (FS-SSFP) [3] and Dixon SSFP [4]. We compared these sequences in normal volunteers in terms of SNR, CNR, fat saturation, and diagnostic quality at 3.0T.

Methods: Ten knees (five volunteers) were imaged using a GE Signa VH/i 3.0T scanner and a quadrature extremity coil. 3D-SPGR was done with TR/TE 13.5/1.5 ms, flip angle of 10 degrees and 3 signal averages for a scan time of 9:41. FS-SSFP was done with TR/TE 5.6/1.5 ms, TI 89 ms, flip angle of 30 degrees, and one signal average for a scan time of 3:20. Dixon SSFP was done with TR/TE 5.1/1.3 ms (three TE increments of 0.6 ms), flip angle of 30 degrees, and three acquisitions for a scan time of 3:40. All scans were 256x256 matrix, 17 cm field-of-view, 1.5 mm section thickness, 52 sections, and acquisition bandwidth of +/- 62.5 kHz. Flip angles were optimized for maximum cartilage SNR. Dixon images were reconstructed on-line using an iterative, least-squares algorithm [5].

       Two experienced radiologists compared the images. SNR was measured from regions of interest in the trochlear cartilage and fluid in the patellofemoral joint. 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). Image quality and fat saturation results were compared using a Wilcoxon signed rank test.

Results: Dixon SSFP produced images with the highest cartilage and fluid SNR (Figure 1). This was statistically higher than FS-SSFP and FS-SPGR ($p < .01$). Contrast-to-noise ratio (CNR) between cartilage and fluid for the three sequences was highest for Dixon SSFP (37.8) followed by FS-SSFP (15.3) and SPGR (4.0). Despite having the longest scan time, the FS-SPGR sequence had the poorest SNR and contrast between cartilage and fluid (Figure 2). The Dixon SSFP sequence also allowed reconstruction of recombined images (Figure 2D).

       Image quality was graded between good and excellent for Dixon SSFP (2.8) and FS-SPGR (2.7), both of which were significantly better than FS-SSFP (2.0; $p < .01$). Fat saturation for Dixon SSFP (2.8) was not statistically different than FS-SPGR (3.0). Fat saturation for FS-SPGR was significantly better than FS-SSFP (3.0 vs. 2.7; $p < .04$).

Conclusion: SSPF provides a fast, SNR efficient method for examining articular cartilage at 3.0T. 3D-SPGR provides excellent depiction of cartilage, but is slow and has relatively poor SNR. FS-SSFP provides better SNR but slightly poorer fat saturation. Dixon SSFP provided the best combination of SNR and CNR of the three sequences tested, and was graded as having an equal image quality to SPGR in about one-third the scan time. The ability to provide recombined fat and water images that correct for chemical shift may allow assessment of subchondral bone thickness [5]. Our results indicate that Dixon SSFP is a highly promising technique for imaging articular cartilage thickness and volume at 3.0T.
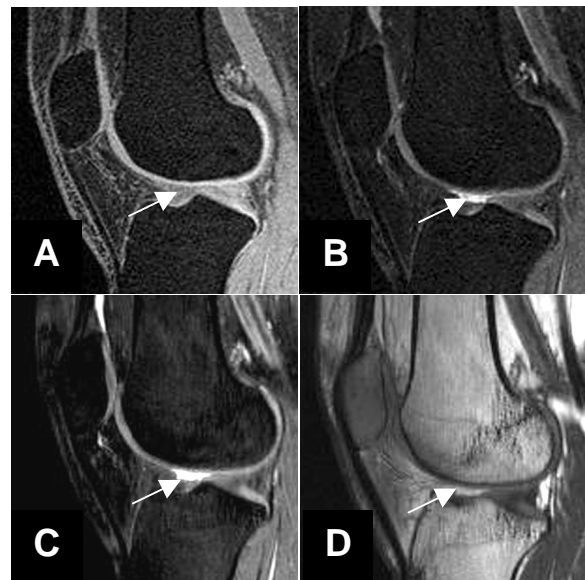
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Acknowledgements
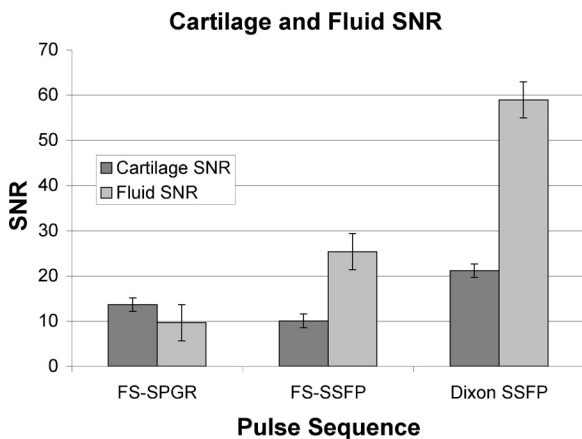
Figure 1: SNR Comparison of pulse sequences.

Figure 2: Images from a healthy volunteer. Joint fluid (arrows) is bright on the SSFP-based techniques, but dark on FS-SPGR. A) FS-SPGR, scan time 9:41. B) FS-SSFP, scan time 3:20. C) Dixon SSFP water image, scan time 3:40. D) Recombined Dixon SSFP water/fat image.