3D-FSE-Cube for Rapid Assessment of Cartilage Morphology in the Knee

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Introduction: Clinical imaging protocols and longitudinal studies of osteoarthritis (OA) often use a combination of two-dimensional fast spin-echo (2D-FSE) for internal derangements of the knee and high-resolution 3D spoiled gradient echo (3D-SPGR) for articular cartilage [1-2]. However, 2D-FSE is limited by its anisotropic voxels, blurring due to intermediate T2-weighting, and magnetization transfer. Three-dimensional FSE with modulated refocusing flip angles [3-7] remedies these limitations by allowing for isotropic voxels that enable multi-planar reconstructions and, hypothetically, accurate cartilage volume measurements. In this study, we evaluate 3D-FSE-Cube, an isotropic fast spin-echo acquisition using a variable refocusing flip angle eXtended Echo Train Acquisition (XETA [3]) and 2D-accelerated auto-calibrated parallel imaging (ARC [4]) for imaging the knee at 3.0T.

Methods: Five knees of healthy volunteers were imaged using a GE Signa HDx 3.0T MRI scanner (GE Healthcare, Milwaukee, WI) and an 8-channel knee coil. Iterative Decomposition of water and fat with Echo Asymmetry and Least squares estimation (IDEAL) SPGR [8] was done with a TR/TE of 16/8 ms, bandwidth of $\pm$ 31.25 kHz, 14-degree flip angle, 384 x 224 matrix, 15 cm field-of-view, 1 mm slice thickness, 90 slices, parallel imaging (acceleration factor of 2), and 5:07 scan time. 3D-FSE-Cube used TR/TE of 2220/24, bandwidth of $\pm$ 31.25 kHz, echo train length of 44, 256 x 256 matrix, 0.5 NEX, 15 cm field-of-view, 0.7 mm slice thickness, 200 slices, fat-saturation, parallel imaging (acceleration factor of 3.48), and 5:00 scan time. Signal-to-noise ratio (SNR) in each subject was calculated by dividing the average measured signal from 5 regions of interest in the trochlear cartilage by the standard deviation of the noise. Since noise distribution varies spatially in parallel imaging, the SNR values for IDEAL-SPGR and 3D-FSE-Cube images are estimations [9]. Contrast-to-noise ratio (CNR) was calculated by subtracting the cartilage SNR from the fluid SNR. Cartilage volume was measured by segmentation of water frequency IDEAL-SPGR and 3D-FSE-Cube images with OsiriX (www.osirix-viewer.com; version 2.7.5). An experienced observer supervised segmentation. SNR, CNR, and cartilage volumes were pair-wise compared between the two sequences using a student t-test.

Results: IDEAL-SPGR produced images with statistically higher cartilage SNR (156.0 $\pm$ 8.2 vs. 60.6 $\pm$ 5.3, $p < 0.0001$) than 3D-FSE-Cube, likely due to its shorter echo time (Figure 1). Nonetheless, all images had excellent depiction of cartilage (Figure 2). Fluid SNR (100.3 $\pm$ 11.1 vs. 66.4 $\pm$ 5.8; $p = 0.0005$) was significantly greater with 3D-FSE-Cube than with IDEAL-SPGR (Figure 1). Fluid/cartilage CNR was greater with IDEAL-SPGR than with 3D-FSE-Cube (89.6 $\pm$ 3.9 vs. 39.8 $\pm$ 8.5; $p < 0.0001$). 3D-FSE-Cube images yielded statistically equivalent cartilage volumes to FS-SPGR (Figure 2d) in a faster scan time than IDEAL-SPGR; femoral cartilage volumes were 15.4 $\pm$ 2.1 mL for both IDEAL-SPGR and 3D-FSE-Cube ($p = 0.9997$).

Conclusion: 3D-FSE-Cube provides a fast comprehensive method that combines the advantages of 3D-SPGR and 2D-FSE in assessing acute injuries as well as OA of the knee. 3D-FSE-Cube retains the advantage of 2D-FSE in having bright fluid (Figure 2, a-b, arrows) that contrasts with darker ligaments and menisci, allowing for diagnosis of internal derangements. Additionally, our results indicate that 3D-FSE-Cube has excellent promise for cartilage evaluation, including accurate cartilage volumes. Thus, 3D-FSE-Cube has the potential to replace the clinical imaging protocol of 2D-FSE combined with 3D-SPGR, saving time with its multi-planar reconstructions, as opposed to the multiple acquisitions of 2D-FSE. In conclusion, 3D-FSE-Cube is a highly promising technique that can be used for rapid assessment of the ligaments, menisci, and cartilage of the knee at 3.0T.

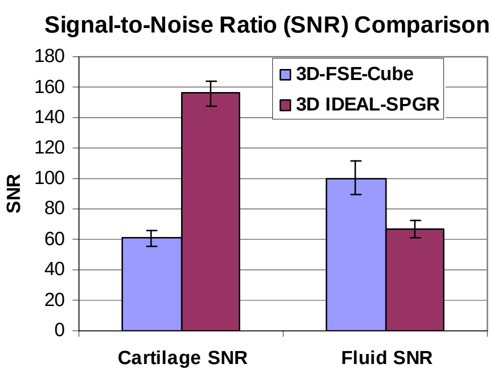

Figure 1: IDEAL-SPGR has significantly higher cartilage SNR ($p < 0.0001$), while 3D-FSE-Cube has significantly higher fluid SNR ($p = 0.0005$).

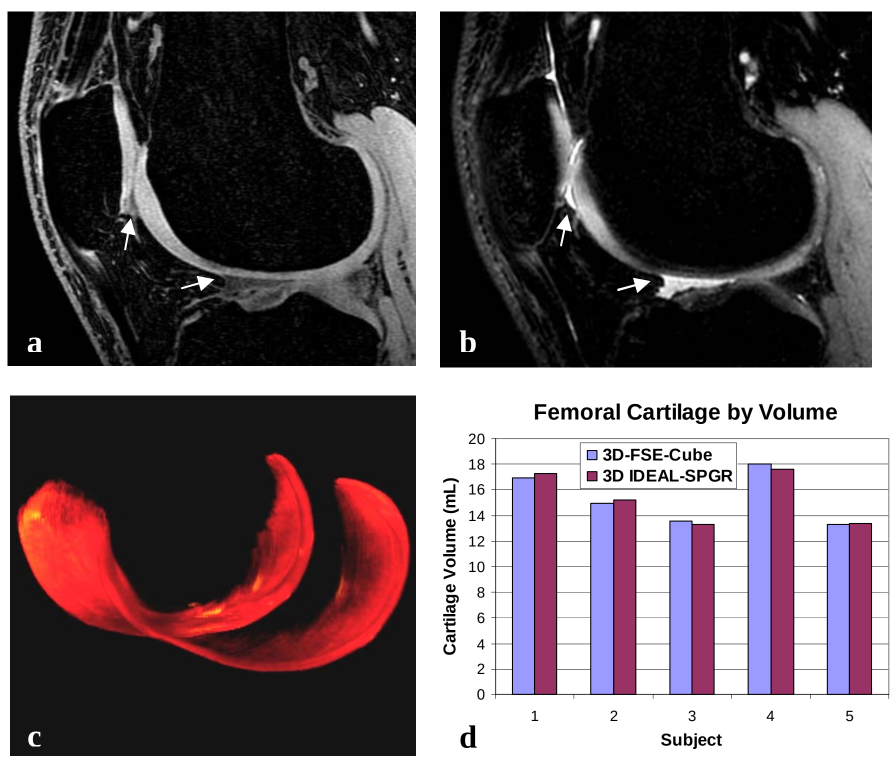

Figure 2: Images from a healthy volunteer. a) IDEAL-SPGR water and b) 3D-FSE-Cube images at 3.0T both show excellent cartilage depiction but different fluid-cartilage contrast, with higher fluid signal (*arrows*) in 3D-FSE-Cube than IDEAL-SPGR. c) Model created from femoral cartilage segmentation of 3D-FSE-Cube images. Cartilage was easily visible from the 3D-FSE-Cube images. d) 3D-FSE-Cube has statistically equivalent cartilage measurements to IDEAL-SPGR ($p > 0.99$).

References

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