Quantitative and Qualitative Assessment of Multiple New 3T Cartilage Imaging MR Pulse Sequences

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Purpose: Multiple new highly SNR efficient cartilage imaging MR pulse sequences have recently been developed. FSE-Cube with extended echo train acquisition (XETA) utilizes refocused flip angle modulation and ky-kz-centric view ordering each shot to minimize TE [1,2]. MENSA is a fully balanced steady-state sequence that utilizes weighted averaging of 2 echoes in the same TR to achieve mixed T2/T1 contrast. IDEAL is a three-point fat-water separation method that uses asymmetric echoes and least squares fitting to achieve the maximum possible SNR performance. IDEAL fat-water separation can be combined with either SPGR [3] or nonspoiled GRASS [4] technique to produce images with dark or bright synovial fluid respectively. COSMIC is a fully-balanced coherent imaging sequence that utilizes segmented multi-shot centric acquisition to achieve mixed T2/T1 and T2 contrast [5]. VIPR-SSFP is a fully balanced steady-state sequence with 3D radial k-space trajectory that produces fat-water separated images with mixed T2/T1 contrast and high isotropic resolution [6,7]. This study was performed to provide a quantitative and qualitative comparison of these new MR pulse sequences for evaluating the articular cartilage of the knee joint at 3T.

Methods: FSE-Cube (.6 mm x .6 mm x .7 mm voxel size), MENSA (.6 mm x .6 mm x .7 mm voxel size), IDEAL-GRASS (.4 mm x .7 mm x 1.0 mm voxel size), IDEAL-SPGR (.4 mm x .7 mm x 1.0 mm voxel size), COSMIC (.6 mm x .6 mm x .7 mm voxel size), and VIPR-SSFP (.4 mm x .4 mm x 1.2 mm effective voxel size with 3 slice averaging of .4 mm isotropic images in one dimension) sequences with 5 minute acquisition times were performed twice on the knees of 10 asymptomatic volunteers and once on the knees of 5 patients with osteoarthritis using a 3T scanner (Signa Excite HDx, GE Healthcare, Waukesha, WI) and an 8-channel phased-array extremity coil. SNR and CNR measurements were performed on the exams of the 10 asymptomatic volunteers using a double acquisition addition/subtraction method previously described for parallel imaging techniques [8]. T-tests were used to compare differences in SNR and CNR between sequences. The MR exams of 5 randomly chosen asymptomatic volunteers and the 5 patients with osteoarthritis were independently reviewed by 3 musculoskeletal radiologists. The radiologists ranked the sequences (1 being best and 6 being worst) based upon the following qualitative measures of image quality: 1) tissue contrast, 2) clarity of articular surface, and 3) cartilage lesion conspicuity. Exact binomial tests were used to compare differences in the ranks given to the sequences.

Results and Discussion: FSE-Cube had the highest cartilage SNR, which was significantly higher (p<.05) than IDEAL-GRASS and VIPR-SSFP. MENSA had the highest synovial fluid SNR, which was significantly higher (p<.05) than FSE-Cube, VIPR-SSFP, and IDEAL-SPGR. COSMIC had the highest CNR between cartilage and synovial fluid, which was significantly higher (p<.05) than FSE-Cube (Figure 1). IDEAL-SPGR had the highest CNR between cartilage and bone, which was significantly higher (p<.05) than IDEAL-GRASS, VIPR-SSFP, and COSMIC (Figure 1). In the subjective comparison, VIPR-SSFP followed by IDEAL-GRASS had the highest rankings for tissue contrast and clarity of articular surface, while FSE-Cube followed by VIPR-SSFP had the highest rankings for cartilage lesion conspicuity (Table 1 and Figures 2 and 3).

Conclusions: This is the first study to compare multiple promising new cartilage imaging MR pulse sequences in the same group of asymptomatic volunteers and patients with knee osteoarthritis. All sequences had certain strengths and weaknesses with no clear cut "winner" in the quantitative and qualitative comparison. The relative advantages and disadvantages of each sequence may make them best suited for different cartilage imaging applications (i.e. cartilage volume measurements vs. early detection of cartilage degeneration vs. cartilage evaluation in post-operative patients with metallic hardware). The study is limited in that it compared sequences with different voxel sizes and different contrast mechanisms. Nevertheless, this information will be useful when developing a focused comparison of the utility of these sequences for providing comprehensive joint and cartilage evaluation in symptomatic patients.

References: [1] Busse RF, et al. ISMRM 2007, p. 1702. [2] Mugler JP, et al. ISMRM 2000, p. 687. [3] Reeder SB, et al. J Magn Reson Imaging 2007; 25:644. [4] Kijowski R, et al. ISMRM 2007, p. 3819. [5] Redpath TW, et al. J Magn Reson Imaging 1988; 6:224. [6] Kijowski R, et al. J Magn Reson Imaging 2006; 24:168. [7] Klaers JL, et. al. ISMRM 2007, p. 3817. [8] Reeder SB, et al. J Magn Reson Imaging 2005; 54:748.
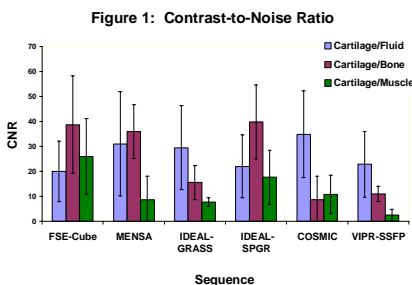

Figure 1: Contrast-to-Noise Ratio

Table 1: Sequence ranking (1 being best and 6 being worse) for qualitative measures of image quality for all reviewers combined.

Subjective Characteristic	FSE-Cube	MENSA	IDEAL-GRASS	IDEAL-SPGR	COSMIC	VIPR-SSFP
Tissue Contrast	3.0*	3.1	2.5	6.0*	4.2*	2.3*
Clarity of Articular Surface	3.8*	4.1*	3.1	4.9*	3.2*	2.1*
Cartilage Lesion Conspicuity	1.8	3.5	3.4	5.9	3.4	2.9

*Statistically significant difference (p<.05) between highest ranked sequence and other sequences
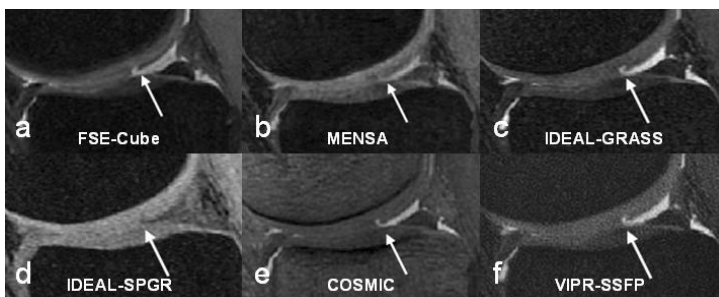

Figure 2: Sagittal (a) FSE-cube, (b) MENSA, (c) IDEAL-GRASS, (d) IDEAL-SPGR, (e) COSMIC, and (f) VIPR-SSFP images of the knee in a patient with osteoarthritis show a superficial partial-thickness cartilage lesion (arrow) on the medial femoral condyle.
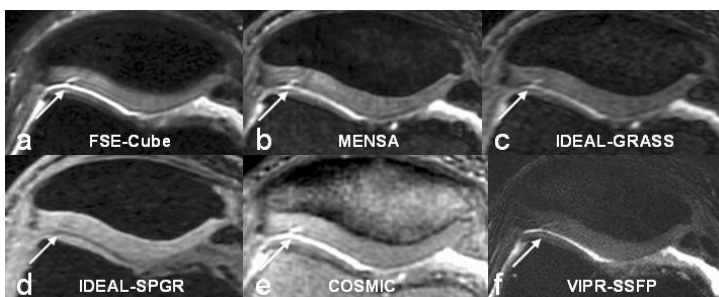

Figure 3: Axial (a) FSE-cube, (b) MENSA, (c) IDEAL-GRASS, (d) IDEAL-SPGR, (e) COSMIC, and (f) VIPR-SSFP reformat images of the knee in a patient with osteoarthritis show a cartilage fissure (arrow) on the lateral facet of the patella.