ACCELERATED MR PROTOCOL FOR CARTILAGE VOLUME ANALYSIS AND 'WHOLE-ORGAN" JOINT ASSESSMENT FOR OSTEOARTHRITIS RESEARCH STUDIES

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Objective: Since osteoarthritis (OA) affects several articular structures and is thought to progress through multiple pathways, the Osteoarthritis Research Society International has recommended that MR protocols used in OA research studies should provide "whole-organ" joint assessment (1). Most "whole-organ" MR protocols are time consuming and consist of 3-dimensional spoiled gradient-echo (SPGR) or dual-echo steady-state (DESS) sequences to evaluate articular cartilage and fast spin-echo (FSE) sequences repeated in multiple planes to evaluate other joint structures (2). Vastly undersampled isotropic projection steady-state free-precession (VIPR-SSFP) is a newly developed MR pulse sequence that can produce water-separated images of the knee joint with isotropic resolution and T2/T1-weighted contrast at both 1.5T and 3.0T (3,4). This study was performed to determine whether an accelerated MR protocol consisting of isotropic resolution VIPR-SSFP and a sagittal fluid sensitive sequence can be used to provide rapid cartilage volume analysis and "whole-organ" joint assessment for OA research studies.

Methods: The study group consisted of 20 consecutive patients with knee OA enrolled in a clinical trial evaluating the efficacy of a newly developed OA therapy. All patients were evaluated at 3.0T using a sagittal VIPR-SSFP sequence (TR/TE: 3.6ms/0.3 and 1.3ms, 15^o flip angle, 0.5mm x 0.5mm x 0.5mm voxel volume, 5:00 min scan time) and a standard 20 minute MR protocol consisting of an axial fat-suppressed T2-weighted FSE sequence (TR/TE: 4000ms/80ms, 0.4mm x 0.6mm x 4.0mm voxel volume, 3:20 min scan time), a coronal fat-suppressed intermediate-weighted FSE sequence (TR/TE: 2000ms/30ms, 0.4mm x 0.6mm x 3.0mm voxel volume, 1:56 min scan time), a sagittal fat-suppressed T2-weighted FSE sequence (TR/TE: 5300ms/80ms, 0.4mm x 0.6mm x 3.0mm voxel volume, 3:16 min scan time), a sagittal intermediate-weighted FSE sequence (TR/TE: 2000ms/20ms, 0.4mm x 0.6mm x 2.0mm voxel volume, 3:26 min scan time), and a sagittal SPGR sequence with IDEAL fat-water separation (TR/TE: 10ms/4.4, 5.4, and 6.1ms, 14^0 flip angle, 0.4mm x 0.8mm x 1.0mm voxel volume, 5:00 min scan time). Cartilage volume measurements were performed using the VIPR-SSFP and IDEAL-SPGR sequences. Two musculoskeletal radiologists independently performed "whole-organ" joint assessment twice at separate sittings using 1) the standard 20 minute MR protocol and 2) an accelerated 8 minute MR protocol consisting of the VIPR-SSFP sequence with multi-planar reformats and the sagittal fat-suppressed T2-weighted FSE sequence. "Whole-organ" joint assessment was performed using the whole-organ magnetic resonance (WORM) system in which numerical values are used to estimate the overall severity of OA and the severity of each individual feature of OA (i.e. cartilage loss, osteophytes, subchondral bone marrow edema (BME), subchondral cysts, medial meniscus (MM) tears, lateral meniscus (LM) tears, anterior cruciate ligament (ACL) tears, posterior cruciate ligament (PCL) tears, medial collateral ligament (MCL) tears, joint effusions, loose bodies, and synovial cysts). Bland-Altman test was used to compare cartilage volume measurements obtained using the VIPR-SSFP and IDEAL-SPGR sequences. Spearman correlation coefficients were used to compare WORM scores obtained using the standard and accelerated MR protocols. Weighted kappa statistics were used to measure interobserver agreement between radiologists for WORM scores obtained using the standard and accelerated MR protocols.

Results: Bland-Altman test showed a very small mean difference of $0.27cm^3$ between cartilage volume measurements obtained using the VIPR-SSFP and IDEAL-SPGR sequences as well as a very narrow confidence interval and no evidence of bias. Cartilage loss, osteophytes, and other MR features of OA were readily identifiable on the multi-planar VIPR-SSFP reformat images with the sagittal fat-suppressed T2-weighted FSE images providing improved conspicuity of subtle bone marrow edema lesions and small subchondral cysts (Figure 1). For both radiologists, there were strong correlations between WORM scores obtained using the standard and accelerated MR protocols (Table 1). There was also similar interobserver agreement between radiologists for WORM scores obtained using the standard and accelerated MR protocols (Table 2).

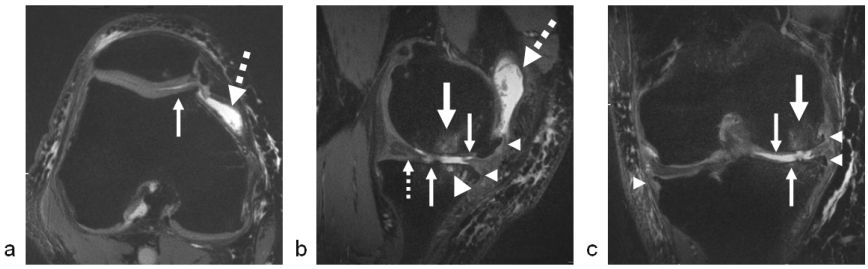

Figure 1: Axial (a), sagittal (b), and coronal (C) VIPR-SSFP reformat images in a patient with knee OA obtained following a single 5 minute acquisition. The VIPR-SSFP images show multiple MR findings of OA including cartilage loss (small arrows), osteophytes (small arrowheads), subchondral bone marrow edema (large arrows), subchondral cysts (large arrowhead), meniscal tear (small dashed arrow), and joint effusion (large dashed arrow)

Table 1: Correlation coefficients comparing WORM scores obtained using the standard and accelerated MR protocols.

WORM Score	Radiologist 1		Radiologist 2	
	Correlation Coefficient	P-Value	Correlation Coefficient	P-Value
Overall WORM Score	0.95	0.0001	0.96	0.0001
WORM Score Cartilage Loss	0.96	0.0001	0.97	0.0001
WORM Score Osteophytes	0.96	0.0001	0.95	0.0001
WORM Score BME	0.90	0.0001	0.88	0.0001
WORM Score Cysts	0.96	0.0001	0.89	0.0001
WORM Score MM Tear	0.76	0.0009	0.98	<0.0001
WORM Score LM Tear	0.93	0.0001	0.85	0.0002
WORM Score ACL Tear	0.93	0.0001	1.00	<0.0001
WORM Score PCL Tear	1.00	<0.0001	1.00	<0.0001
WORM Score MCL Tear	1.00	<0.0001	1.00	<0.0001
WORM Score Joint Effusion	1.00	<0.0001	0.95	0.0001
WORM Score Loose Bodies	0.96	0.0001	0.93	0.0001
WORM Score Synovial Cyst	0.97	0.0001	1.00	<0.0001

Table 2: Interobserver agreement for WORM scores obtained using the standard and accelerated MR protocols.

WORM Score	Kappa Value	
	Standard MR Protocol	Accelerated MR Protocol
Overall WORM Score	0.56	0.58
WORM Score Cartilage Loss	0.54	0.51
WORM Score Osteophytes	0.50	0.58
WORM Score BME	0.21	0.41
WORM Score Cysts	0.50	0.41
WORM Score MM Tear	0.51	0.53
WORM Score LM Tear	0.47	0.66
WORM Score ACL Tear	0.44	0.44
WORM Score PCL Tear	1.00	1.00
WORM Score MCL Tear	1.00	1.00
WORM Score Joint Effusion	0.35	0.27
WORM Score Loose Bodies	0.40	0.44
WORM Score Synovial Cyst	0.72	0.72

Conclusions: An 8 minute accelerated MR protocol consisting of isotropic resolution VIPR-SSFP and sagittal fat-suppressed T2-FSE sequences can provide rapid cartilage volume analysis and "whole-organ" joint assessment for OA research studies which will allow more time for physiologic cartilage imaging sequences to be incorporated into research MR protocols. Ongoing development to improve the fluid sensitivity of VIPR-SSFP may provide even more rapid cartilage volume analysis and whole-organ joint assessment by eliminating the need to include the fat-suppressed T2-weighted FSE sequence in the accelerated MR protocol.

References: 1) Peterfy, et al. Osteoarthritis Cartilage.14:A44-45, 2006. 2) Peterfy, et al. Osteoarthritis Cartilage. 14:A95-111, 2006. 3) Kijowski, et al. Journ Magn Reson Imaging. 24:168-75, 2006 4) Kijowski, et al. ISMRM 2007, abstract 3801. 5) Peerfy, et al. Osteoarthritis Cartilage. 14:A177-190, 2006.