MULTI-ECHO SWI OF KNEE CARTILAGE

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Introduction:

MR imaging is an established tool for the diagnosis of cartilage damage and consequent therapy monitoring [1]. Advanced MR techniques for imaging osteoarthritis (OA) include delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), which measures proteoglycan concentration, and diffusion tensor imaging (DTI), which can measure collagen disruption. However, dGEMRIC requires contrast administration and waiting time and does not provide collagen structure information while DTI's low spatial resolution and signal-to-noise ratio (SNR) as well as long acquisition times limit its clinical applicability [2-3]. Alternatively, the frequency of the susceptibility-weighted (SW) MR signal has proven to be highly sensitive to changes in the tissue's microstructure. Such microstructural alterations may reflect pathologic changes due to disease processes [4-5]. Therefore, multi-echo SWI offers the possibility to image changes to the well-defined architecture of collagen fibres in the human knee at high-spatial resolution. During the progression of OA, the microstructure of collagen is disrupted, and the water-proteoglycan environment is altered, causing changes in tissue biomechanics and leading to further degeneration [6]. Here, we investigated the potential of the multi-echo gradient echo (GRE) signal's magnitude and frequency, and maps of T2* relaxation for assessing articular cartilage damage of OA patients.

Methods:

MRI was performed on four patients (mean age 53.3±2.7), diagnosed with cartilage damage, within two weeks prior to their arthroscopic surgery. The imaging protocol on a Philips Achieva 3.0T scanner using an 8-channel SENSE knee coil included a 3D multi-GRE with 3 echoes, FOV 140x140x71.5 mm^3, voxel size of 0.15x0.15x1.30 mm^3, TR/TE/ΔTE of 37/5/5 ms, 17º flip angle, acquisition time 12.09 min. T2* maps were generated on the scanner, while all SWI processing was performed offline. Phase images were homodyne filtered and frequency maps were generated [7] and averaged over the first 3 echoes. Cartilage abnormalities were confirmed after arthroscopy and were graded using the Outerbridge classification by an orthopaedic surgeon. Regions of interest were identified on average magnitude MR images and compared to arthroscopy.

Results:

Regions of cartilage damage were visible in all patients. Grade I and II changes detected in arthroscopy were visible on average magnitude, and T2* maps. Grade II changes were also observable on MR frequency maps. Figure 1 presents Grade III abnormalities apparent in arthroscopy and MRI. In addition to softening and discolouration, an increased amount of grade III roughness (red arrow) and fibrillation (ellipse) was observable through arthroscopy on the proximal undersurface of the patella (Fig.1A). Fig. 1B-D display corresponding sites of injury on different MR image contrasts. Three discrete hypointense regions were located in the radial zone (Fig. 1B, starred arrows). There was a marked decrease in T2* values in corresponding regions (Fig. 1C). The observed decreases were comparable to similar cartilage studies [8]. Areas of tissue injury were also identifiable as distinct regions of varied signal on MR frequency maps (Fig. 1D).

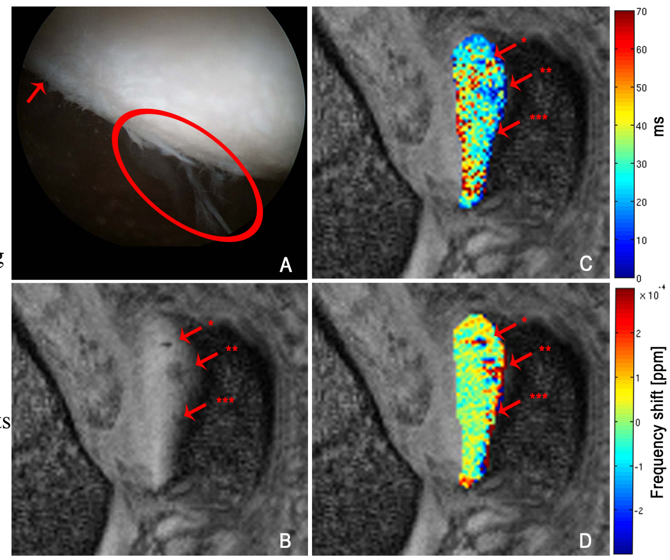

Figure 1. Comparison of arthroscopy (A), average magnitude (B), T2* (C), and frequency (D) of a patient's right patella. Grade III changes marked with arrow and ellipse. Arrows with stars marked MRI abnormalities.

Discussion:

SWI's potential in detecting meniscal tears and iron deposits in the human knee has been reported in previous studies, highlighting its high SNR and sensitivity when compared to conventional scans [9-10]. However, the use of a 3D multi-GRE sequence allows image acquisition at even higher spatial resolution with good SNR, thus enabling us to visualize structural damage in the thin layers of the cartilage. Collagen fibres in the radial zone, as described in the arcade model, are highly anisotropic and are radially arranged from the bone surface. Hence, fibre matrix disorganization would result in the anisotropic regions transforming into isotropic areas of focal collagen disruption [11]. The MR frequency shift signal is suggested to be sensitive to such changes in the tissue's microarchitecture, and recent neuroimaging studies demonstrated the sensitivity of MR frequency mapping to microstructural changes at the cellular and subcellular levels due to different pathological processes [7].

Conclusion:

This study demonstrates the use of different SW contrasts to visualize OA-related changes in knee cartilage. 3D multi-GRE may complement conventional MRI techniques for investigating OA due to its high spatial resolution, SNR, and image contrasts (magnitude, T2*, frequency) that can be obtained from a single acquisition.

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