Evaluation in patients with early osteoarthritis of hip joint cartilage caused either by femoro-acetabular impingement (FAI) or by acetabular dysplasia (AD) using T1rho values and T2 values at 3.0 Tesla: an MRI work-in-progress

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Purpose

Introduction

Osteoarthritis (OA) of the hip is a major cause of disability in 1-6% of the population, and one of the most common musculoskeletal system diseases in the elderly. The exact mechanisms for development of OA are not fully understood; however, aberrant hip anatomy found in acetabular dysplasia (AD) or femoroacetabular impingement (FAI) has been recognized as a cause for early OA of the hip joint. In AD, a reduced load-transferring area and subsequent extensive stresses on the cartilage due to the shallow acetabulum is thought to promote early OA.

FAI leads to mechanical impaction involving the proximal femur and acetabular rim, which can result in labral failure and varying degrees of cartilage damage. FAI can be divided into Cam, Pincer, and mixed types. The Cam type results from the nonspherical shape of the femoral head and an insufficient femoral head-neck offset. It leads to both cartilage shearing during hip flexion by the femoral head-neck and the separation of cartilage, subchondral bone, and the acetabular labrum. The Pincer type arises from excessive anterior acetabular coverage, which causes continuous frontal contact between the femoral neck and the acetabular labrum during flexion. The mixed type is a combination of the Cam and Pincer types.

Recently, many reports have shown that FAI is an important pathogenic factor for early onset of primary OA of the hip in young adults. Untreated FAI can lead to premature osteoarthritis of the hip, and surgical treatment is often necessary to both delay the onset of OA and manage symptoms. Thus, early diagnosis of FAI and concurrent OA is important for good surgical outcomes.

Standard radiographs reveal important information about osseous structural abnormalities of the hip and, in combination with clinical evaluation, aid the investigator in diagnosis of FAI. This method is insensitive to early damage since joint space narrowing, osteophytes, and subchondral sclerosis occur only with advanced cartilage degeneration. Therefore, standard radiography is not suitable as an early diagnostic tool for planning preserving hip joint surgery. Neither traditional magnetic resonance (MR) imaging nor MR arthrography can be used to discriminate between normal cartilage and cartilage with diminished functional capacity.

Some current advances in cartilage imaging have focused on identifying improved methods for delineating the biochemical changes of early cartilage damage. Hence, biochemical MR imaging techniques at 3.0 T have been developed to detect very early cartilage degeneration. Recent studies of knee cartilage have shown that biochemical
MR techniques such as T2 mapping, dGEMRIC, and T1rho may provide complementary information on early degeneration of proteoglycan and collagen in cartilage.

T2 mapping is currently the most widely used biochemical MR imaging. It is sensitive to collagen and water, the two main components of articular cartilage. However, few published studies have evaluated the sensitivity of quantitative T2 mapping for very early detection of hip cartilage disorders and degeneration. Proteoglycan depletion is believed to be one of earliest steps in OA, preceding alteration in collagen structure. Recent studies have shown that T1rho can be used to image proteoglycan depletion, as T1rho is less susceptible to factors such as lack of background homogeneity, susceptibility variations, diffusion-induced signal losses, and the "magic angle artefact." T1rho also has a dynamic range within cartilage, and can show larger differences between normal and OA subjects compared to T2 mapping. T1rho imaging may therefore be a better imaging technique than T2 mapping for the detection of early cartilage degeneration.

Some authors have evaluated early degeneration of hip joint cartilage using dGEMRIC. These studies have shown that this biochemical MR imaging technique is very sensitive to proteoglycan changes of hip cartilage; however, the technique requires an intravenous injection of a gadolinium contrast agent followed by a variable exercise regime. Thus, another advantage of the T1rho method is that it does not require any contrast agent. Moreover, the T1rho method can be implemented in a clinical environment without the need for hardware modification.

To the best of our knowledge, only one evaluation of T1rho values for hip joint cartilage has been published. We hypothesized that the T1rho method would enable earlier detection than T2 mapping of very early OA of the hip joint caused by developmental dysplasia or femoroacetabular impingement. Thus, the aims of this study are as follows: 1) to compare cartilage damage as seen on T1rho and T2 mapping in cases of AD or FAI; and 2) to correlate arthroscopy findings with MR imaging using T1rho and T2 mapping.

**Methods and Materials**

Six patients (mean age±standard deviation (SD), 22±8.4 years; range, 14 to 41 years) were examined at 3.0 T using both T1rho and T2 mapping. Two patients had FAI and four patients had AD. Patients with developmental dysplasia were included if the The lateral centre edge was below 25° or the anterior center edge was below 20°. FAI was diagnosed based on clinical examination findings (positive anterior impingement sign) in combination with radiographic features of a Cam deformity (radiographs and MRI with an alpha-angle ≥55° on both modalities measured using 90° flexion-abduction radiographs (Dunn)) or features of a Pincer deformity (positive cross over sign and/or positive wall
sign), according to the definition published by Beck et al. Exclusion criteria included the following: prior hip surgery; history of hip trauma; cases with slopped capital femoral epiphysis; rheumatoid arthritis; high dose corticosteroid use; avascular necrosis; and contra-indications to MR imaging.

All MR exams were conducted at 3.0 T (Philips Achieva QD R.3.1.1.2. MR scanner, Koninklijke Philips Electronics N.V., Eindhoven, The Netherlands) using a body matrix phased array coil. The coil was accurately placed, with confirmation, on top of the joint to examine each hip in patients in the supine position before scanning. Parameters for sagittal T1-weighted fast spin echo (FSE) imaging were as follows: repetition time (TR)/echo time (TE) = 600/10 ms; field of view (FOV) = 15 cm; matrix = 512×512; bandwidth = 230 Hz/pixel; and number of excitations (NEX) = 1. Parameters for sagittal T2 mapping were as follows: TR = 2671 ms; TE = 16, 32, 48, 64, 80, and 96 ms, FOV = 200×200 mm, matrix = 256×256; thickness = 4.0 mm, gap = 0 mm; 20 slices, echo train length (ETL) = 6, and scan time = 22 min 52 s. Parameters for proton density-weighted SPIR images were as follows: TR/TE = 4000/20 ms, FOV = 15 cm, matrix = 512×512, bandwidth = 289.7 Hz/pixel, thickness = 3 mm, gap = 1 mm, number of slices = 24, echo train length (ETL) = 6, and NEX = 1.

Sagittal T1rho-weighted images were obtained using the spin-lock technique and spiral image acquisition. The following acquisition parameters were used for 3D-balanced-TFE: TR/TE = 4.8/2.4 ms, 20 interleaves/slice, 4096 points/interleaf, FOV = 15 cm, matrix = 256×256, effective in-plane spatial resolution = 0.58×0.58 mm, slice thickness = 4 mm, number of slices = 20, time of spin-lock (TSL) = 1/10/20/30/40 ms, flip angle = 50°, spectral presaturation of inversion recovery (SPIR) fat saturation with a spin-lock frequency = 759.5 Hz/pixel, and a total acquisition time of 12 min 42 s. MRI scans were performed in one continuous session without removing the subject from the scanner. T1rho maps of hyaline cartilage were reconstructed by fitting the T1rho-weighted image intensity pixel-by-pixel with Eq. 1 (see below) using an in-house Levenberg-Marquardt mono-exponential fitting algorithm written in C as follows:

\[ S(TSL) \# \text{exp}(-TSL/T1\text{rho}) \quad (1) \]

where TSL is the time of spin lock and S is the signal intensity in a T1rho-weighted image with a certain TSL. MR images were transferred to a Dell workstation (Dell Inc., Round Rock, TX, USA) for off-line quantification of cartilage T1rho relaxation times.

The mid-acetabulum was selected to determine cartilage segmentation for evaluating T1rho values and T2 mapping. The central and peripheral cartilage zones were assessed separately, and the mid-point between the fossa acetabuli and acetabular rim was defined as the border between central and peripheral in a selected sagittal slice. Care was taken
while manually drawing the region of interest (ROI) within the cartilage boundaries to prevent the region from extending into the bone tissue (Fig. 1).

**Fig. 1**: Fig. 1 Example of manual ROI selection on a proton density MR image for central and peripheral regions of articular cartilage. Each ROI comprised both cartilage surfaces.

**References**: Department of Radiology, Kobe University School of Medicine - Kobe/JP
Because the study only included six patients, no statistical comparisons were performed. Average T1rho values were calculated and T2 mapping was performed in the peripheral and central cartilage in cases of femoroacetabular impingement and developmental dysplasia.

**Images for this section:**
**Fig. 1:** Fig. 1 Example of manual ROI selection on a proton density MR image for central and peripheral regions of articular cartilage. Each ROI comprised both cartilage surfaces.
Results

Descriptive T1rho values and T2 mapping data for FAI and AD are shown in Table 1.

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<tr>
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**Table 1**: Table 1 T1rho values and T2 maps in patients with FAI and AD.

**References**: Department of Radiology, Kobe University School of Medicine - Kobe/JP and represented graphically in Fig. 2.
Fig. 2: Fig. 2 Average T1rho and T2 values in the central and peripheral cartilage for all six patients.

References: Department of Radiology, Kobe University School of Medicine - Kobe/JP
Comparison of central and peripheral cartilage revealed that both T1rho and T2 mapping tended to show higher values in peripheral cartilage than in central cartilage.
Fig. 3: Fig. 3 An FAI patient: No cartilage disorders were detected by arthroscopy. T1rho values and T2 mapping both showed high signal intensity in the deep layer of the cartilage. Surgery showed a cartilage disorder in the deep layer of the cartilage.

References: Department of Radiology, Kobe University School of Medicine - Kobe/JP

Figure 3 demonstrates how biochemical MR imaging may be superior to arthroscopy.
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Conclusion

T1rho and T2 mapping may have the potential to detect early degeneration of hip joint cartilage caused by either FAI or AD in patients with early osteoarthritis.

References

References


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