

Bone marrow edema-like lesions and cartilage degeneration in osteoarthritis using 3T MR T1rho quantification: longitudinal assessment

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INTRODUCTION

Bone marrow edema-like lesions (BMEL) are defined as areas of high signal intensity in T₂-weighted, fat-saturated magnetic resonance (MR) images or in short inversion time inversion-recovery images. These lesions are present in knee osteoarthritis (OA) and acute knee injuries. While MR findings of BMEL are common, our knowledge concerning their natural history and significance is limited. In OA, BMEL has been associated with the severity and progression and pain in OA (1,2). The goal of this study was to quantitatively assess the spatial relationship between bone marrow edema-like lesions (BMEL) and the associated cartilage in knee OA using T_{1ρ} quantification at 3T MRI, cross-sectionally and longitudinally with one-year follow-up.

METHODS

Twenty-three patients (10 male, 13 female, mean age 51.8 ± 11.2 years) with clinically diagnosed knee OA underwent MRI at 3T (Signa, GE Medical Systems). Among them, twelve patients (5 male, 7 female, mean age 51.5 ± 12.1 years) were performed 3T MRI at one year follow-up. The MRI protocol included sagittal intermediate-weighted fat-saturated FSE images (matrix 512×256, FOV = 16 cm slice thickness = 2 mm), sagittal 3D water excitation high-resolution SPGR images (matrix 512×512, FOV = 16 cm, slice thickness = 1mm) and sagittal 3D T_{1ρ} quantitation sequences based on MAPSS sequence previously developed in our lab (3) (matrix 256×128, slice thickness = 4 mm, time of spin lock (TSL) = 0/10/40/80 ms, spin lock frequency = 500Hz). Radiographs were also obtained and scored based on Kellgren-Lawrence (KL) scales (number of patients = 10, 10, 2, 1 for KL = 1, 2, 3, 4 respectively).

BMEL were semi-automatically segmented in FSE images and the 3D volumes of BMEL were calculated in both baseline and follow-up patients. The signal intensity (SI) increase of BMEL versus normal bone marrow (NBM) was calculated as: $(SI_{\text{BMEL}} - SI_{\text{NBM}}) / SI_{\text{NBM}} \times 100\%$. Cartilage degeneration was graded using modified Whole-Organ MRI Score (WORMS) (4) in each compartment as well as in cartilage overlying BMELs in the FSE images. Cartilage was segmented semi-automatically in SPGR images using an in-house developed software. Five compartments were defined: patellar, lateral/medial femoral condyle (LFC/MFC), lateral/medial tibia condyle (LT/MT). 3D cartilage contour was overlaid to aligned T_{1ρ} maps. T_{1ρ} values were calculated from each defined compartments, as well as from cartilage overlying BMEL. Cartilage degeneration percentage was used to evaluate cartilage overlying BMEL (OC) and surrounding cartilage (SC) change between follow up and baseline. Cartilage degeneration percentage was calculated using T_{1ρ} value of OC and SC basing on: (follow up - baseline) / baseline.

Signed rank test was used to compare the cartilage degeneration percentage of BMEL overlying and surrounding cartilage. A paired t-test was used to compare the T_{1ρ} and clinical grading of BMEL-overlying cartilage and surrounding cartilage between baseline and follow up, respectively. A Student's t-test was used to compare BMEL volume and SI increase between baseline and follow up. The Pearson correlation coefficients were calculated between BMEL-overlying cartilage T_{1ρ} and BMEL volume, and between BMEL-overlying cartilage T_{1ρ} and BMEL SI increase, respectively.

RESULTS

At baseline, 25 BMELs were found in 16 out of 23 patients (volume 2.88 ± 3.21 cm³; SI increase 265% ± 110%): 11 in patella, 8 in LFC, 3 in MFC, 2 in MT and one in LT. For 12 patients who had both baseline and follow up exams, 14 BMELs were found in 10 patients at both baseline and follow-up. No significant differences were found in volume and SI increase of BMEL between baseline and follow up. For volume, 6 BMELs increased (change more than 5%) in follow up, 5 decreased, and 3 remained stable. For SI increase, 9 BMELs increased (change more than 5%) in follow up, while 4 decreased, 1 remained stable.

At baseline, the overall T_{1ρ} values were significantly increased in patients with BMEL compared with those without BMEL (42.5 ± 3.8 ms vs 39.6 ± 1.1 ms, P = 0.012). At follow-up, no comparison was made for overall T_{1ρ} values between patients with and without BMEL due to small number of patients without BMEL (n=2). At both baseline and follow-up, both T_{1ρ} values and WORMS grading were significantly elevated in OC compared to SC (Table 1). From baseline to one-year follow up, T_{1ρ} values in OC increased 7.8% ± 5.0%, which is significantly higher than that in SC (3.1% ± 4.0%, P=0.05). No significant differences in WORMS grading change from baseline to follow-up were found in SC vs. OC. Increased T_{1ρ} values in OC were correlated with increased SI of BMEL in both baseline and follow-up (R = 0.55, P = 0.005 for baseline, R = 0.54, P = 0.005 for follow-up), but not correlated with BMEL volume (R = 0.1, P = 0.63).

Table 1 T_{1ρ} values and WORMS grading of cartilage overlying (OC) and surrounding (SC) BMEL at baseline and 1-year follow-up in OA patients.

	T _{1ρ} values (ms)			WORMS grading		
	OC	SC	P value	OC	SC	P value
Baseline	46.46±3.09	41.37±3.12	0.0006	4.73±1.49	1.18±1.47	0.00005
Follow-up	48.63±2.90	43.03±2.36	0.0005	5.09±1.38	1.45±1.51	0.00003

DISCUSSION

Patients with BMEL showed overall higher T_{1ρ} values in cartilage compared with those who had no BMEL, suggesting BMEL may be correlated with disease severity of OA. Furthermore, in patients with BMEL, both T_{1ρ} values and WORMS grading were elevated in cartilage overlying BMEL, suggesting a local spatial correlation between BMEL and more advanced cartilage degeneration. In this study, we found the degree of T_{1ρ} elevation in BMEL-overlying cartilage is correlated with signal intensity increase of BMEL, but not with the volume of BMEL. At one-year follow up, cartilage overlying BMEL showed higher T_{1ρ} value increase compared with surrounding cartilage, suggesting BMEL is indicative of accelerated cartilage degeneration. Interestingly, no such difference was found using WORMS scoring. This result suggests that quantitative cartilage imaging, such as T_{1ρ}, may be a more sensitive indicator of cartilage degeneration than semi-quantitative scoring systems.

REFERENCES

1. Felson et al, Ann Intern Med 2001; 2. Felson et al, Ann Intern Med 2003; 3. Li X et al, MRM 2008; 4. Peterfy et al, Osteoarthritis Cartilage 2004

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