Longitudinal evaluation of cartilage degeneration in ACL-injured knees using MR T1rho quantification – A preliminary study

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INTRODUCTION

Anterior cruciate ligament (ACL) injuries are one of the most common ligament injuries at the knee. Recent long-term studies have demonstrated that 50-70% of the ACL-injured patients have radiological evidence of osteoarthritis (OA) 10-15 years after ACL injury, despite ACL reconstruction (1,2). Magnetic resonance imaging (MRI) has been used widely for detecting and monitoring joint injuries. Conventional MRI, however, is limited to probing primarily morphologic changes of the joint. In particular, bone marrow edema-like lesions (BMEL), or bone bruises, are defined as hyperintensities in T_2-weighted, fat-saturated MR images. BMELs are present in up to 80% of acute ACL injuries (3,4). However, their natural history and clinical significance are not known. Previous work reported significantly elevated $T_{1\rho}$ relaxation time values in BMEL-overlying cartilage (5), indicating potential degeneration in these regions. The goal of this study was to longitudinally evaluate the cartilage degeneration in ACL-injured knees using MR $T_{1\rho}$ relaxation time quantification.

MATERIALS AND METHODS

Fourteen patients with acute knee ACL injuries and showed BMEL (four female and 10 male; mean age = 31.4 years, age range = 20 – 46 years) were scanned at a 3T GE Excite Signa MR scanner using a transmit/receive quadrature knee coil within 2-3 months post injury and prior to surgery. Among these 14 patients, 6 patients were scanned two-week, six-month and one-year after ACL reconstruction. The imaging protocol consisted of sagittal T_2-weighted fat-saturated fast spin-echo (FSE) images and sagittal 3D water excitation high-resolution spoiled gradient-echo (SPGR) images, followed by a $T_{1\rho}$ quantification sequence developed previously (5) (FOV=14 cm, slice thickness = 3 mm, time of spin-lock = 0/10/40/80 ms, spin lock frequency = 500 Hz) and a 3D MR spectroscopic imaging (MRSI) sequence. BMEL was semi-automatically segmented using a thresholding method based on T2-weighted images and volume of BMEL was calculated. BMEL caused by surgical intervention (close to screw, and distinguishable from baseline BMEL) was not included. $T_{1\rho}$ maps were reconstructed by fitting the $T_{1\rho}$ weighted images pixel-by-pixel. $T_{1\rho}$ maps and T2-weighted images were aligned to SPGR images. Cartilage was segmented semi-automatically in SPGR images. From this, 3D contours for BMEL-overlying cartilage and surrounding cartilage were defined. These contours were overlaid to $T_{1\rho}$ maps, and the mean and standard deviation of $T_{1\rho}$ values were calculated. The follow-up images were registered to the baseline images acquired prior to surgeries. $T_{1\rho}$ values in the overlying cartilage of the baseline BMEL (not the BMEL during follow-up) were calculated and compared with the surrounding cartilage during follow-up exams. Non-parametric rank tests were used to compare average $T_{1\rho}$ between BMEL-overlying cartilage and surrounding cartilage both at baseline and follow-up, and to compare $T_{1\rho}$ values between baseline and follow-up in both lateral and medial compartments.

RESULTS

The volume of BMEL in lateral femoral condyle (LFC) and lateral tibia (LT) decreased significantly from baseline (prior to surgery) to one-year follow-up (7.4 ± 5.1 cm^3 vs. 0.5 ± 0.9 cm^3, $P < 0.05$, Fig. 1(a)). The BMEL-overlying cartilage in LT showed significantly higher $T_{1\rho}$ values at both baseline and one-year follow-up (45.6 ± 14.9 ms vs. 33.7 ± 11.3 ms, $P < 0.05$ for baseline, 46.4 ± 4.6 ms vs. 33.2 ± 2.6 ms, $P < 0.05$ for one-year follow-up). Fig. 1(b) illustrates one example patient. No significant difference in $T_{1\rho}$ values between BEML-overlying and surrounding cartilage in LFC was found. In the medial side, $T_{1\rho}$ values were slightly higher in MFC and MT at one-year follow-up than baseline, however, the difference was not significant with this small sample size (39.6 ± 0.1 ms vs. 37.5 ± 3.2 ms, $P = 0.07$ for MFC and 33.2 ± 0.3 ms vs. 29.8 ± 7.6 ms, $P = 0.34$ for MT).

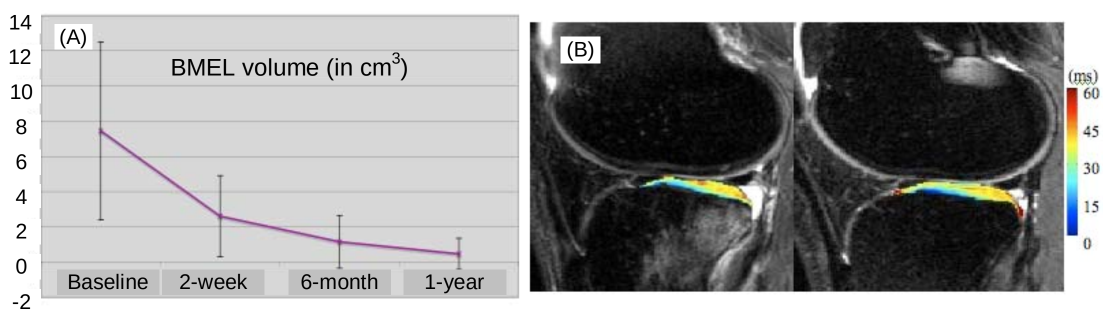

Fig 1. (a) BMEL volume decreased significantly as time progressed after injuries. (b) $T_{1\rho}$ values in the posterior lateral tibial plateau overlying initial BMEL were significantly higher in baseline (left) and one-year follow-up (right) even if the BMEL resolved at one-year post injury.

DISCUSSION

Previous studies have proposed that the BMEL-overlying cartilage may have sustained irreversible injury during impact of acute injuries (6). $T_{1\rho}$ quantification in cartilage provides quantitative assessment of potential early cartilage degeneration in knee injuries. Significantly elevated $T_{1\rho}$ values in BMEL-overlying cartilage were observed at both baseline and follow-up, despite resolution of BMEL at follow-up, indicating potential degeneration in these regions. $T_{1\rho}$ values in medial compartments were slightly higher at one-year follow-up than at baseline, potentially due to change of loading even after ACL reconstruction. Further investigation with more patients is warranted to test the significance. This very preliminary data suggested that there is potential early degeneration in cartilage of ACL-injured knees even after ACL-reconstruction and resolution of BMEL, which may eventually lead to osteoarthritis. Advanced MRI techniques will allow us to critically evaluate these early biochemical changes.

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