Quantitative Assessment of Bone Marrow Edema Pattern and Associated Cartilage in Osteoarthritic and ACL-Injured Knees Using High Field MR Imaging and Spectroscopy

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Introduction: While MR findings of bone marrow edema pattern (BMEP) are common in knee osteoarthritis (OA) and acute injuries such as anterior cruciate ligament (ACL) tear, our knowledge concerning their natural history and clinical significance is limited. In OA, BMEP has been associated with disease progression and pain in OA (1, 2). In ACL tears, previous studies have proposed that the BMEP-overlying cartilage has sustained irreversible degeneration during injuries (3). MR T1ρ relaxation time has been proposed to probe changes in cartilage matrix during early stages of OA (4–6). Proton MR spectroscopy (MRS) provides a non-invasive method for quantifying biochemical or metabolic changes in tissues, but few studies have investigated MRS in knee bone marrow. The objectives of this study were to quantitatively evaluate BMEP and the associated cartilage in patients with OA and ACL-injured knees using T1ρ quantitation and 3D MR spectroscopic imaging (MRSI).

Materials and Methods: Eight healthy volunteers, 10 patients with knee OA and 14 with ACL tears were studied. All patients had BMEP. The patients with ACL injuries were scanned within two months of the injury and prior to surgery. All images were acquired at a 3T GE MR scanner (General Electric, Milwaukee, WI). The imaging protocol included sagittal T2-weighted fat-saturated FSE images, sagittal 3D water excitation high-resolution SPGR images and 3D T1ρ quantitation sequences as previously developed. 3D MRSI data were obtained using a Point REsolved Spectral Selection (PRESS) volume selection technique, with spectral box covering BMEP as much as possible, and to include some normal-appearing bone marrow as internal references. Cartilage was segmented semi-automatically in SPGR images. 3D cartilage contour was overlaid to aligned T1ρ maps. T1ρ z-scores (normalized T1ρ values using control data) from BMEP-overlying cartilage were calculated and compared with surrounding cartilage in the same compartment. Water, saturated-lipids and unsaturated lipids were quantified from 3D MRSI data. Volumes of significantly elevated water and unsaturated lipids were calculated for each patient. Water content, defined as water/(water+lipids), and unsaturation index, defined as unsaturated lipids/total lipids, were calculated within and outside BMEP.

Results: The mean T1ρ z-scores of BMEP-overlying cartilage in lateral tibia of patients with ACL tears was significantly higher than that in surrounding cartilage (2.2 ± 3.1 vs. 0.3 ± 2.3, P < 0.001), Fig. 1. However, no significant difference was observed in lateral femoral condyle compartment of patients with ACL tears. The mean T1ρ z-score in BMEP-overlying cartilage was higher than that of surrounding cartilage in patients with OA, but not significantly (1.9 ± 3.1 vs. 1.0 ± 2.1, P = 0.37). The volume of elevated water correlated significantly with the volume of BMEP (R=75.5%, P < 0.001). The water content was significantly higher within BMEP-overlying cartilage (21.8 ± 9.9 % vs. 14.3 ± 5.9 %, P = 0.002), Fig. 2. The unsaturation index outside BMEP in patients with ACL tears was significantly higher than that outside BMEP in patients with OA (2.7 ± 1.3 % vs. 1.7 ± 0.8 %, P = 0.04).

Discussion: 3D MRSI in bone marrow and MR T1ρ quantification in cartilage provide quantitative assessment of cartilage and bone in knee OA and knee injuries. Higher T1ρ in BMEP-overlying cartilage may be indicator of cartilage degeneration in these regions. Significantly elevated water and unsaturation lipids were observed in BMEP using 3D MRSI. BMEP in acute injuries (ACL-tear) may have different biochemical composition (changes in water and lipids) from those lesions in OA. These advanced MR techniques can be valuable tools for non-invasive diagnosis and treatment follow-up for OA and knee injuries, which may lead to improvement of non-operative and operative interventions.

4. Duvvuri et al, MRM 1997
5. Regatte et al, Acad Radio 2002

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