Parametric T2-mapping in young patients with patellofemoral disease

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INTRODUCTION

Disorders of the patellofemoral joint are one of the most common musculoskeletal disorders of high socioeconomic relevance as they occur most frequently in young and active patients encountered in orthopaedics and sports medicine. If left untreated, severe and chronic conditions such as osteoarthritis (OA) or patellofemoral disease (PFD) may develop (1). Yet, despite of the high incidence, and the abundance of research, little is known about etiology and natural history of patellofemoral disorders (2). A frequent association with dysplastic features of the patellofemoral joint, in particular trochlear dysplasia and patella alta is known. Patella alta (high riding patella in relation to the femur) has been shown to reduce the contact area of the patella with the femoral trochlea, thereby increasing patellofemoral forces and at times cartilage wear. The damaged area is typically very focal, concentrated on the inferior lateral patella facet and surrounded by healthy cartilage. Surgical procedures typically involve "realigning" the patella in relationship to its groove, in an attempt to improve function. The improved patella position also increases contact area by reducing lateral patella tilt and/ or patella alta (3).

Although clinical MRI has evolved as the most important noninvasive method for structural joint assessment, it is still lacking in sensitivity to early changes. Relaxometry measurements, such as free precession T_2 and longitudinal rotating frame relaxation during continuous wave (CW) irradiation $T_{1\rho}$, have been studied as a tools for cartilage evaluation (4), however, have not yet significantly impacted standard of care and arthroscopic techniques remain the gold standard. We implemented measurement of T2 relaxation time as part of the standard MRI assessment of prospective patellofemoral surgery patients at 3T. The hypothesis of the study was that in the future, with T2 mapping, we will be able to identify early cartilage wear or early cartilage disease in young patients who have symptomatic patellofemoral pain/instability, and follow the cartilage health over time, including its response to specific interventions including surgery and physical therapy interventions.

METHODS

MRIs were obtained on a 3.0 Tesla scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) using a 15-channel knee coil. A routine clinical protocol using (proton density (PD)-, T1-, and T2-weighted Turbo-Spin-Echo (TSE) was performed in axial, sagittal, and coronal planes. For parametric measurement of T2 relaxation time in sagittal and axial planes, a multi-echo—spin-echo sequence with a TR of 2,400 ms and nine echo times (10, 20, 30, 40, 50, 60, 70, 80 and 90 ms) was utilized. The field of view was approximately 115 x 140 mm with in-plane resolution of 0.5 x 0.5 mm and slice thickness of 2.0 mm with 0.2 mm slice gaps. The bandwidth was 300 Hz/pixel, 25 slices were acquired, and total acquisition time was 11:34 minutes. T2 relaxation times were calculated fitting the exponential decay pixel-by-pixel using inline software provided by the scanner vendor.

Regions of interest (ROIs) in the patellar cartilage were manually drawn using OsiriX for each patient (N=10) in the axial plane. Starting from the median ridge, the cartilage was divided into 0.5cm sections towards medial and lateral borders. Flattened projections of the T2 relaxation time within the respective ROIs of each patient's cartilage were created with MATLAB. Patient specific ROIs with T2 values in the top 20% were determined to be "hot" for the respective individual. The hot-spot location in cranio-caudal direction was measured from the base of the patellar cartilage. In addition, the Insall-Salvati (I-S) ratio was measured (5).

Figure 1. I-S ratio vs. normalized location of hot spot. The distance was normalized by the length of the patellar cartilage in cranio-caudal direction.

RESULTS

An inverse relationship between the I-S ratio and the location of the patellar hot spot was observed. As the I-S ratio increased, the location of the hot spot was shown to present on a more inferior portion of the patellar cartilage (Fig. 1). Among the patients, the average difference between hot spot T2 and the rest of the [healthier] cartilage was 24.9 ms. From the flattened projections, the size, shape, layout, and T2 values of the cartilage could be visualized (Fig. 2). The location of the hot spot, as seen in the flattened ROI projection is indicated on the axial and sagittal PD-weighted TSE images (Fig. 2).

Figure 2. Flattened projection of the T2 ROIs with median ridge indicated in gray (A), sagittal (B) and axial (C) views of patellar cartilage showing locations of detected cartilage degradation. T2 map demonstrated elevated values lateral of the median ridge. Both anatomic MR images indicated cartilage damage in the same location.
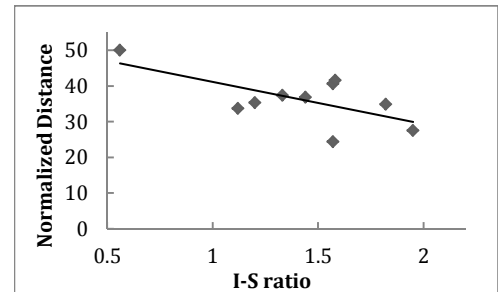
DISCUSSION

The correlation between an increase in the I-S ratio, a measure of the degree of patella alta relative to the femur, and a more inferior hot spot on the patellar cartilage indicated that there may be a very focal biomechanical friction point associated with the patella alta condition. As the patella is abnormally high riding in these patients excessive stresses could induce very focal damage to the articular cartilage on a more inferior portion of the patellar cartilage. If patella alta is not corrected, the cartilage at the friction point may continue to be damaged due to the reduction in contact area. This provides further evidence to the already growing body of information that PFD is a precursor to OA (1,2). The flattened ROI projection offers a very informative way of presenting the parametric MRI assessment of cartilage to an orthopaedic surgeon, further aiding in the surgery planning and postsurgical planning. T2 mapping proves to be very sensitive to detect these focal changes and could provide prognostic value in patient management.
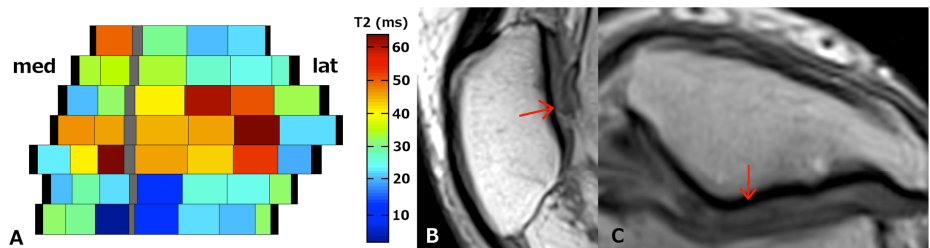
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