

T₂ Relaxation Times in Medial Compartment Osteoarthritis using 3D Quantitative DESS (qDESS)

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Introduction

Osteoarthritis (OA) is a chronic, degenerative disease of the whole joint, disabling 10% of the population over 60, and costing as much as \$60 billion each year (1). Advances in magnetic resonance imaging (MRI) have enabled improved visualization and quantification of early, OA-related changes to articular cartilage. One method, T₂ mapping, provides an accurate measure of tissue relaxation time, with increased values correlating with changes in cartilage water content and collagen structure (2). The purpose of this study was to evaluate two-dimensional fast-spin echo (2D-FSE) and quantitative three-dimensional (3D) Dual-Echo Steady State (qDESS) (3) T₂ mapping methods for assessing articular knee cartilage in both healthy volunteers and patients with single-compartment OA.

Methods

Acquisition: We scanned the knees of four patients with Kellgren-Lawrence grade 1 or 2 OA of the medial compartment (2 males, 2 females) and nine healthy, asymptomatic volunteers (4 males, 5 females). All knees were imaged at 3.0 Tesla in the sagittal plane using a Discovery MR750 scanner (GE Healthcare, Waukesha, WI) and an 8-channel transmit-receive knee coil (Invivo Inc., Gainesville, FL). 2D-FSE T₂ images were acquired using TR/TE 1500/8.1, 16.2, 24.3, 32.4, 40.4, 48.5, 56.6, 64.7ms, 320x160 matrix size, 3mm slice thickness, 16cm FOV, and receiver bandwidth \pm 41 kHz with a 12 minute imaging time. The 3D qDESS images were obtained with a 29ms TR, TE of 10 and 48 ms for the two echoes, spoiler gradient duration of 2ms, 384x256 matrix size, receiver bandwidth \pm 31.25kHz, 16cm FOV, and 3mm slice thickness with a total imaging time of 10 minutes. One set had a 35° flip angle and spoiler gradient amplitude of 1.0ms*mT/m per axis and the other had an 18° flip angle and spoiler gradient amplitude=8.0ms*mT/m on all axes.

Analysis: Cartilage was manually segmented in 10 regions of interest (ROIs) using OsiriX. Two slices showing maximum cartilage were selected in the central medial and lateral femur for both imaging techniques. T₂ fit maps were generated and T₂ relaxation times were measured. The following ROIs were evaluated: medial/lateral anterior, central, and posterior femoral condyle and medial/lateral anterior and posterior tibial cartilage. Pearson correlations were used to assess the correlation of imaging methods. A one-way ANOVA was used to compare relaxation times in cartilage from OA patients to healthy volunteers. A paired t-test was used to evaluate the difference between 2D-FSE and qDESS T₂ relaxation times.

Results

qDESS T₂ relaxation times were strongly correlated with 2D-FSE T₂ relaxation times ($r=0.732$, $p<0.01$) in the entire, 13-subject population and when healthy volunteers ($r=0.678$, $p<0.01$) and OA patients ($r=0.760$, $p<0.01$) were analyzed separately. Overall, average qDESS T₂ relaxation times were significantly elevated in OA patients (37.0 ms) compared with healthy volunteers (34.0 ms, $p=0.001$, Figure 1). This significant trend was also observed when comparing mean 2D-FSE T₂ measurements in OA subjects and healthy volunteers (43.2 vs. 39.8 ms, $p<0.001$). T₂ measurements for five ROIs in the medial compartment using qDESS and 2D-FSE showed consistent elevation in OA cartilage (Figure 2). No significant results were observed in the lateral compartment. In the entire study population, the mean cartilage T₂ value measured with 2D-FSE (40.9 ms) was significantly greater than the mean cartilage T₂ value measured using qDESS (34.9 ms, $p<0.01$).

Conclusion

T₂ relaxation times calculated from qDESS are strongly correlated with the values obtained from 2D-FSE T₂ maps, particularly in patients with OA. This result suggests that qDESS is sensitive to the macromolecular changes characteristic of OA progression in articular cartilage. qDESS is a more rapid, 3D acquisition with no slice gaps. We observed consistent and significantly increased T₂ values with 2D-FSE compared with qDESS. Recent literature has shown a clear increase in measured T₂ with 2D-FSE compared with spin echo, which is probably due to stimulated echoes in the FSE acquisition (4). qDESS T₂ values are well-correlated with spin echo measurements (3), suggesting the difference in T₂ values seen in our results is likely due to over-estimation of T₂ by 2D-FSE. In addition, qDESS is a true 3D acquisition that can also be made sensitive to apparent diffusion coefficient (3), which may provide additional information on the disease state of cartilage in OA (5).

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References 1. Buckwalter et al. Adv Drug Deliv Rev 2006; 58:150-167. 2. Gold et al. AJR 2009;193:628-38. 3. Staroswiecki E. et al. #500. ISMRM 2011. 4. Pai et al. MRI 2008; 26(9):1215-20. 5. Raya, et al. Invest Radiol 2011.

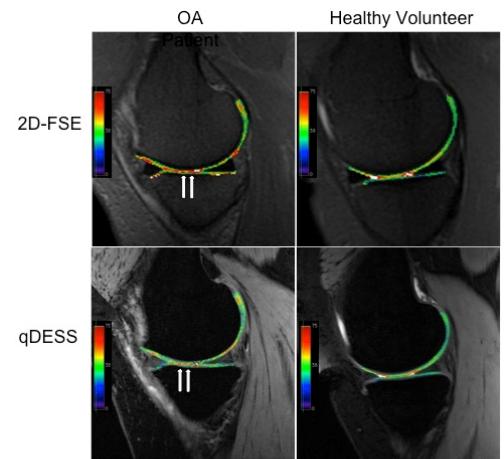


Figure 1. T₂ Maps overlaid on 2D-FSE images (top) and qDESS images (bottom) of the medial femur and tibia in an OA patient and healthy volunteer. Arrows indicate areas of elevated T₂ in OA cartilage compared with healthy volunteers.

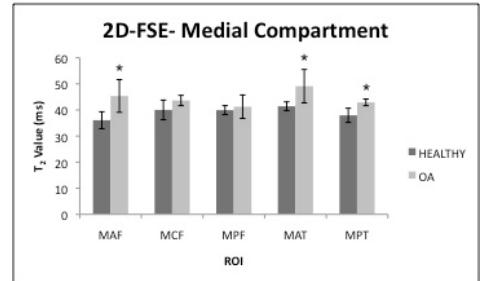
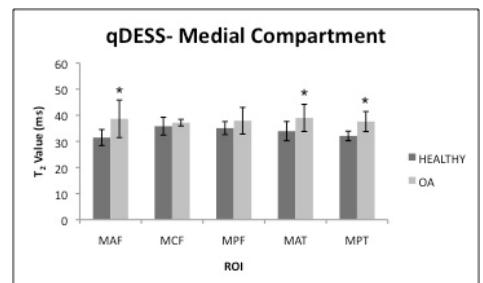


Figure 2. Comparison of T₂ measurements in five ROIs in the medial compartment using qDESS (top) and 2D-FSE (bottom). Both techniques demonstrate consistent elevation of T₂ measurements in OA cartilage. Significance is denoted with an asterisk ($p<0.05$).