Repeatability and age-related change of sodium in the knee articular cartilage measured with sodium MRI

S. Koo[1], E. Staroswiecki[1,2], N. Bangerter[3], B. Hargreaves[1], and G. Gold[1]

[1]Radiology, Stanford University, Stanford, CA, United States, [2]Electrical Engineering, Stanford University, Stanford, CA, United States, [3]Electrical & Computer Engineering, Brigham Young University, Provo, UT, United States

Introduction

Aging is one of the leading risk factors for osteoarthritis **[1]**. Proteoglycan, one of the major components of articular cartilage, undergoes loss and structural changes with aging **[2]**. Proteoglycan has a negative fixed charge density, which is balanced by positively charged sodium in the cartilage. Imaging of cartilage sodium is a potential tool to evaluate spatial proteoglycan content and cartilage degeneration **[3]**. Sodium MRI has been demonstrated as a desirable imaging modality to detect proteoglycan loss in cartilage **[3,4]**. The objectives of this study were twofold. The first was to understand the association between cartilage sodium content (as assessed with sodium MRI) and aging. We hypothesized that sodium content in cartilage would decrease with aging. The second objective was to test the repeatability of cartilage sodium content measurement using sodium MRI to assess the variability of the measurements at multiple time points.

Methods

Sodium MR images were taken for 15 healthy knees from 7 males and 8 females (age 32.2±7.4 ranging from 21 to 48 years) using a GE Signa Excite 3.0T MRI scanner (GE Healthcare, Milwaukee, WI) and a custom quadrature sodium knee coil. Sagittal plane images were obtained using a fast gradient-spoiled sequence with TR/TE 35/0.6 ms, flip angle 70 degrees and 28 signal averages **[5]**. Image resolution was 1.25x1.25x4 mm and scan time was 21minutes.

Four out of the fifteen volunteers underwent the same scan protocol again between 24 and 48 hours after the first scan to measure the repeatability. A 100-mmol-concentration test tube of saline was placed within the sodium coil to normalize the inter-scan signal variability. Cartilage sodium signal was measured from three regions in the knee – medial and lateral regions in the tibiofemoral cartilage (Med TF & Lat TF) and a region in the patellofemoral cartilage (PatFem) in OsiriX **[6]** as shown in Fig 1. The cartilage sodium signal was divided by the tube sodium signal for normalization.

To test the hypothesis we calculated the Pearson's correlation coefficients between the age and normalized sodium signal for the three regions. Also we tested the mean normalized sodium signal difference between younger (≤ median age of the subjects, 31) and older groups using Student's t-test for the three regions. The day-to-day variability of the normalized sodium signal of the three regions for 4 volunteers was measured.

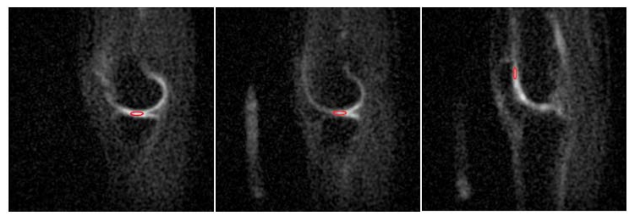

Fig 1. Sodium Knee MRI and the regions of interest in the medial (left) and lateral (middle) tibiofemoral cartilage and the patellofemoral cartilage

Results

The average (±SD) signal to noise ratio of the tube and the cartilage was 18.8±5.0 and 26.5±7.6, respectively. There was no significant correlation between the age and the normalized sodium signal. Also there was no significant difference in normalized sodium signal between the younger and older groups for all three regions (Fig 2). Interestingly, the medial tibiofemoral cartilage (average signal =1.62) had significantly higher signal than the lateral tibiofemoral cartilage (average signal=1.34) and patellofemoral cartilage (average signal=1.27) (Fig 3). The variability was not significantly different between the three regions. The average variability of the normalized sodium signal for all regions was 6.6% between the two time points ranging from 3.0% to 8.6% for the four subjects.

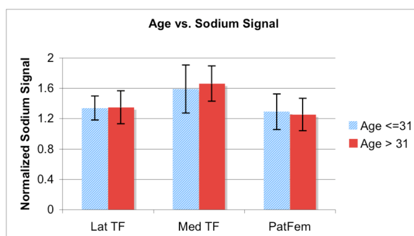

Fig 2. Comparison of normalized signal between younger and older groups

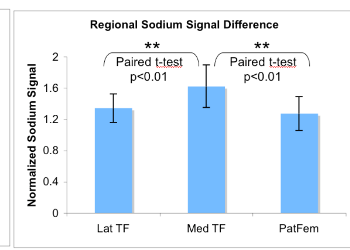

Fig 3. Comparison of normalized signal between the three regions

Discussion

The results showed that there was no significant age-related change in the cartilage sodium contents for the relatively young adults whose average (±SD) age was 32.2±7.4. It may require a much larger age range and a larger cohort to see age-related change in cartilage sodium content. Interestingly, the medial tibiofemoral cartilage had significantly higher sodium signal than other regions, which may represent the adaptation of biochemical contents of the cartilage to the biomechanical loading condition in the knee with higher loading in the medial than lateral compartments during walking **[7]**. The average variability of the sodium MRI for the 24 to 48 hour interval was 6.6% which may include both the variability of the sodium in the tissues and the variability inherent to the imaging technique. The variability of the imaging technique could be improved with a better control for a consistent flip angle and B1 correction. We need further clinical studies to understand the sensitivity of the sodium MRI to cartilage disease and determine the repeatability of this technique to use this imaging method in a clinical setting.

References

[1] Oliveria SA et al., Arthritis Rheum 38(8):1134-41, 1995. [2] Buckwalter JA et al., Microsc Res Tech 28(5):398-408, 1994. [3] Reddy R et al., Magn Reson Med 39(5):697-701, 1998. [4] Wheaton AJ et al., Radiology 231(3):900-5, 2004. [5] Staroswiecki et al., Proc. 15th ISMRM p. 384, 2007. [6] Rosset A et al., J Digit Imaging 7(3):205-16, 2004. [7] Koo S et al., J Biomech 40(13):2961-6, 2007.

Acknowledgements

NIH EB002524-05, NIH EB005790-04, GlaxoSmithKline, GE Healthcare.