Abstract

Osteoarthritis (OA) is a degenerative disease affecting molecular composition of cartilage of Knee. Early detection of OA is critical for preventing the progression and reverting the course of the disease when the cost of the treatment is low and treatment success rate is much higher. Early stage of OA is associated with the loss of Glycosaminoglycan which are side chains of Proteoglycan (PG) molecules from the Extracellular Matrix of cartilage. Currently available non-invasive methods to measure PG have limitations in either specificity, sensitivity or spatial resolution. A recently developed method known as Chemical Exchange Saturation Transfer (gag)MR Images PG non-invasively. While this method is highly specific to Glycosaminoglycan (GAG), current implementation of this method is based on single slice, time intensive and not conducive for routine evaluation of patients. In this study, a novel 3D / multi-slice gagCEST imaging technique is developed to image PG of human knee cartilages in a practically achievable scan time with reproducible results at 7T MRI

Materials and Methods

- Five healthy volunteers of age 32.8 ± 14 yrs underwent MRI at whole body 7T scanner (Siemens Healthcare, Erlangen, Germany) using a 28-channel Knee Coil (Quality Electrodynamics, OH, USA). Three volunteers were scanned twice to determine reproducibility.
- A new 3D gagCEST sequence has been developed as shown in the figure below. The preparation block consists of a CEST preparation. Readout is done with very low flip (5°) angle spoiled gradient echo segments (~600 per shot with a GRAPPA factor of 2 along phase encoding direction) to obtain rapid 3D images
- Elliptical center encoding strategy was used for the phase-slice encode plane. Using this view ordering and ‘burst mode’ shots strategy, high throughput rate (>80%) for readout is achieved.
- Imaging parameters
  - 140 mm FOV with 0.6X0.6X3 mm³ resolution for 234x234x16 matrix size.
  - TR/TE = 7.5/3 msec with 5° flip angle, 2 shots with 8sec shot TR , GRAPPA factor = 2
  - B1 GRE => 30° and 60° flip angle method, without GRAPPA
  - WASSR B0map => 200 msec duration with 20 Hz power for 0:0.1:0:8 ppm offsets
  - gagCEST => 500 msec duration for 0.2:0.1:1.8 ppm offsets (1ppm center for gag)

Background

Briefly, gagCEST technique selectively saturates the exchangeable hydroxyl protons of GAG by the application of radio frequency (RF) pulse; the saturated protons of GAG exchange with protons of bulk water leads to a reduced bulk water signal, which is concentration dependent

Materials and Methods

Results

- Figure: A. 3D multi-slice gagCEST maps of cartilages of a healthy young volunteer
- B. gagCEST maps of 65-year old subject with knee pain showing reduced patellar cartilage thickness and gagCEST values.
1. Axial orientation showing patellar cartilage
2. Coronal orientation showing Femoral (on top) and Tibial cartilages
Note: The gagCEST maps are overlaid on anatomical image and cropped

Results (contd.)

Figure: gagCEST values of healthy volunteers calculated from cartilages of different compartments of knee
A. M1 Normalized
B. M0 Normalized

Conclusion

- To the best of our knowledge, this is the first study reporting 3D multi-slice gagCEST of various compartments of human knee at 7T
- We have developed a highly reproducible MRI technique to quantify GAG at a practically achievable scan time
- There has been a lot of interests shown by doctors and pharmaceutical industry to diagnose the health of cartilage non-invasively to determine patient response to a particular drug under development
- Work is in progress to evaluate more healthy subjects and patients with Knee pain

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References:

1. Ling et al, Proceedings of the National Academy of Science 2008:105(7):2266-2270