Uniform-MT CEST to isolate gagCEST contrast from asymmetric MT effects: First in vivo study on human knees at 7 T

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Target Audience: Researchers interested in chemical exchange saturation transfer (CEST) and/or magnetization transfer (MT) MRI methodology in general and degenerative joint diseases such as osteoarthritis (OA) in particular.

Purpose: The extracelluar matrix of articular cartilage is mostly composed of type II collagen and proteoglycan (PG) aggregates with glycosaminoglycan (GAG) chains. Osteoarthritis (OA) is characterized by the loss of PGs in cartilage, and therefore in-vivo quantification of GAG concentration is important for the early diagnosis of OA. One promising method for measuring GAG content in articular cartilage is CEST[1]. Measurement of this so-called gagCEST may be affected by the MT effects resulting from the background extracelluar matrix. Recently, we have proposed a new strategy to disentangle CEST effects from asymmetric MT effects by using a simultaneous two-frequency RF irradiation technique to make the MT effects uniform[2]. In this work, we compare for the first time the uniform-MT (uMT) CEST method to the conventional CEST method through an in vivo human knee MRI study at 7 T.

Method: A schematic of the MRI pulse sequences used in this study is shown in Fig. 1. A segmented GRE acquisition with centric phase encoding order was used for imaging, with Flip Angle = 10°, TR = 24 ms, TE = 3.5 ms, dwell time = 15 μs, FOV = 160 × 160 mm^2, slice thickness = 5 mm, matrix size = 196 × 196. The image is acquired in two segments (m = 2). For the off-resonance presaturation, a train of 10 Gaussian and cosine-modulated Gaussian pulses were used in the conventional and uMT CEST experiments, respectively, each 100 ms long, with their offset frequencies being varied from -3600 Hz to 3600 Hz with a step size of 100 Hz. Their nominal flip angles were 1800° ($B_{1,rms}$ = 0.53 μT) and 3600° ($B_{1,rms}$ = 0.76 μT) for the conventional and uMT CEST experiments, respectively. The cosine-modulated Gaussian pulse was modulated at a frequency of 1.8 kHz. For the conventional CEST experiment, a B_0 map was obtained from the WASSR acquisition[3], in which a train of two 100 ms-long 180° gauss pulses was used during the pre-saturation and the offset frequency was varied from -720 Hz to 720 Hz with a step size of 20 Hz. For the uMT CEST experiment, a B_0 map was obtained pixel wise from the middle positions of two minima around ±1800 Hz in the Z spectrum. The right knees of five healthy volunteers (male, mean age 31.0 ± 4.3 years) have been scanned.

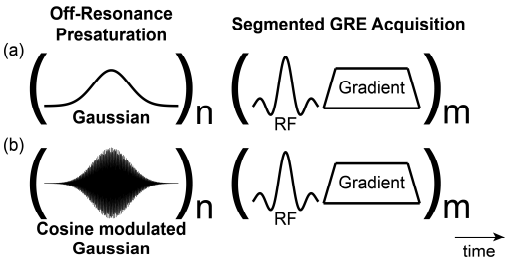

Fig. 1 MRI pulse sequences used for the (a) conventional and (b) uMT CEST experiments. A train of preparation pulses (n = 10) is applied prior to the segmented GRE imaging sequence (m = 2).

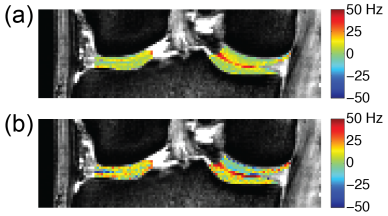

Fig. 2 gagCEST contrast in the articular cartilage of a healthy volunteer from the (a) conventional and (b) uMT CEST methods.

Results: Fig. 2 shows the B_0-corrected gagCEST maps in the cartilage of one of the volunteers, obtained from the conventional and uMT CEST methods. The gagCEST contrast was evaluated as an integration of $[M_{z,sat}(-\Delta) - M_{z,sat}(+\Delta)]/M_0$ over Δ between 0 Hz to 600 Hz. Fig. 3 shows an MT contrast map obtained from the uMT CEST experiments, by comparing the results when the frequency offset for the saturation pulse was 0 Hz with the reference image without any saturating pulse. Pixels with the MT contrast higher than 50% were segmented, and their MT asymmetry curves are shown in Fig. 4.

Discussion: The MT asymmetry in the uMT CEST experiment was close to zero for the larger frequency offsets (1200 Hz ~ 1800 Hz), which has been observed in all five volunteers. Therefore, the MT asymmetry at the smaller frequency offsets (0 Hz ~ 600 Hz) may reflect the pure gagCEST contrast more accurately. The MT contrast map can be useful for separating articular cartilage tissue from synovial fluids.

Conclusion: The preliminary results of this work suggest that the uMT CEST method can reduce the asymmetric MT interferences in measuring gagCEST contrast and that it can be a better diagnosis tool for OA.

Fig. 3 MT contrast in the articular cartilage of a healthy volunteer.

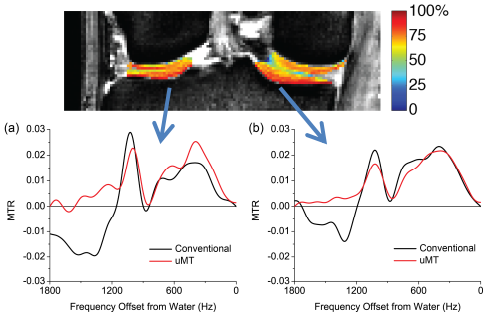

Fig. 4 MT asymmetry curves in pixels with larger MT effects on the (a) lateral and (b) medial femorotibial cartilage.

References: 1. Ling W, Regatte RR, Navon G, Jerschow A, Assessment of glycosaminoglycan concentration in vivo by chemical exchange-dependent saturation transfer (gagCEST). PNAS 2008;105(7):2266-2270.
2. Lee JS, Regatte RR, Jerschow A, Isolating chemical exchange saturation transfer contrast from magnetization transfer asymmetry under two-frequency rf irradiation. J. Magn. Reson. 2012;215:56-63.
3. Kim M, Gillen J, Landman BA, Zhou J, van Zijl PCM. Water saturation shift referencing (WASSR) for chemical exchange saturation transfer (CEST) experiments. Magn. Reson. Med. 2009;61(6):1441-1450.