T2 of articular cartilage in the presence of Gd-DTPA(2-)

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INTRODUCTION

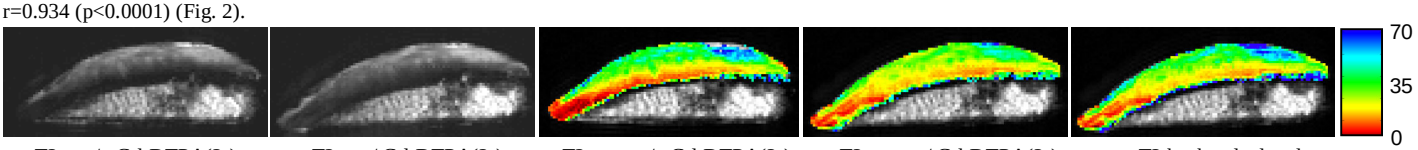
T2 and dGEMRIC (delayed Gadolinium Enhanced MRI of Cartilage) are two techniques for characterization of articular cartilage. They are currently measured in separate studies since Gd-DTPA(2-), needed for dGEMRIC, provides a competing relaxation pathway to the inherent T2 mechanisms. The aims of this study were to measure how large an effect Gd-DTPA(2-) has relative to the inherent T2 mechanisms, and to determine if the inherent information can be back-calculated using a T2 map in the presence of Gd-DTPA(2-).

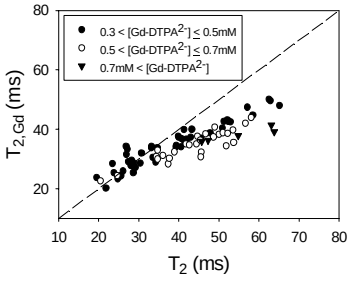
METHODS

Twenty sections (2-mm section thickness, 200-µm in-plane resolution) from two osteochondral samples were T2 mapped at 8.45T (multi-slice CPMG sequence, TR=3000/ 5000 ms, 8 echoes with TE=10-80 ms) before and after equilibration in 1mM Gd-DTPA(2-) solution. Both T2–weighted images (comparable to clinical assessment routines) and T2 maps were assessed, and for further analysis 80 regions-of-interest (10-36 pixels in each) were selected at different tissue depths to represent cartilage with a variety of Gd-DTPA(2-) concentrations and T2s. Finally, T2 maps of all imaging sections were back-calculated (T2bc) on a pixel-by-pixel basis from the maps of T2 in the presence of GdDTPA(2-) (T2Gd) with the equation T2bc = 1/(1/T2Gd - r2[Gd-DTPA(2-)]). For this back-calculation, r2 was taken as 9.27 (mM-sec)(-1), determined from a macromolecular phantom of 20% skim milk powder by weight. T1 in the presence of Gd-DTPA(2-) was imaged (multi-slice inversion recovery sequence, TE=10ms, TR=1500/2000 ms, and 8 or 9 TIs between 17-600 ms) to obtain the map of Gd-DTPA(2-) concentration assuming a single T1-relaxivity (r1=4.7(1/mMs)) and T1 without GdDTPA(2-) value of 1.57s. For clinical studies, T2 maps were obtained from 2 volunteers with and without Gd-DTPA(2-) (double dose Magnevist (Berlex, NJ)) on a 1.5T MRI system.

RESULTS

Deep cartilage with relatively short T2 was not significantly affected by Gd-DTPA(2-) either in terms of T2 contrast or T2 maps (Fig. 1). While T2-weighted images were not visually altered even in areas of high T2 and/or high [Gd-DTPA(2-)], T2 maps were noticeably affected in these regions with decrease in conspicuity of high T2 lesions. A further ROI-analysis confirmed the intuition that tissue areas with high T2s and/or high [Gd-DTPA(2-)] are most affected (Fig. 2). Back-calculation was applied to all twenty sections. It restored the T2 lesions seen in the inherent T2 maps, and in ROIs, the back-calculated T2 values were highly correlated to T2 with r=0.934 (p<0.0001) (Fig. 2).





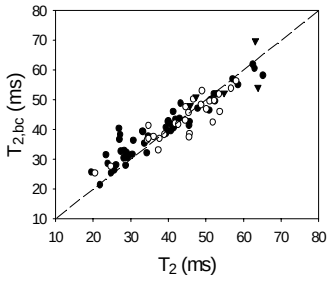
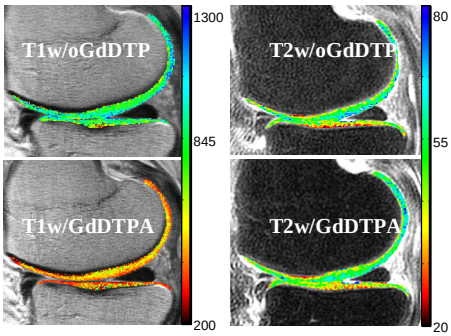


Fig. 1 (above): T2 images *in vitro* in the absence and presence of Gd-DTPA(2-): T2–weighted image contrast (TE=40ms) is not strongly effected even in the presence of high (1 mM) equilibrating Gd-DTPA(2-). Quantitative T2 values are affected, but are restored with back-calculation of T2 using single values for relaxivity and the Gd-DTPA(2-) concentration calculated from T1 maps (dGEMRIC).

Fig. 2 (left): The effect of Gd-DTPA(2-) on cartilage T2 in ROIs (n=80) of human cartilage samples. Higher T2s (weaker inherent T2 relaxation mechanisms) and tissue areas with higher Gd-DTPA(2-) (low GAG) for a given equilibrating concentration are more affected by the Gd-DTPA(2-). The back-calculated T2s restore the inherent T2 values.



Clinical images demonstrated the expected variation of T2 with depth. However, T2 was not appreciably impacted with and without Gd-DTPA(2-) (double dose Magnevist, as used for dGEMRIC) (Figure 3).

Fig. 3 (left): T1 (left) and T2 (right) images acquired *in vivo* without (top) and with (bottom) Gd-DTPA(2-). T1 is substantially different (50% change) in the presence of GdDPTA(2-) demonstrating the effective penetration of the contrast agent. (Note the color scale is not one typically used in dGEMRIC studies in order to have the T1 without and with GdDTPA(2-) on the same scale.) However, the mean T2 of 10 small ROIs at different depths across condyle are not significantly different in the absence and presence of GdDTPA(2-), demonstrating that the clinical (dGEMRIC) dose of GdDTPA(2-) does not present a significant source of T2 relaxation relative to the inherent T2 relaxation mechanisms in cartilage.

DISCUSSION

The inherent T2 of cartilage is due to interactions of interstitial water with cartilage macromolecules. The results here demonstrated that Gd-DTPA(2-) provides an additional, non-negligible mechanism for T2 relaxation with relatively high (1 mM) equilibrating Gd-DTPA(2-) concentration. While T2-weighted image contrast, and short T2 relaxation times typically found in deep cartilage zone, remained unaffected, lesions conspicuity in T2 maps could be decreased or lost in areas with high T2 and/or high local Gd-DTPA(2-) concentration. The results also demonstrate that the effects of Gd-DTPA(2-) on T2 maps can be compensated by back-calculating the inherent T2 from T2Gd and [Gd-DTPA(2-)] obtained from dGEMRIC. Overall the assumptions applied in back-calculation provided satisfactory correction to T2 values affected by Gd-DTPA(2-). The pilot clinical findings demonstrate that the Gd-DTPA(2-) concentration used in clinical studies may be low enough to preclude the need for correcting schemes. Thus, concurrent T2 and dGEMRIC measurements should be feasible for both bench and clinical studies.