INTRODUCTION Delayed gadolinium enhanced MRI of cartilage (dGEMRIC) has been demonstrated as a technique for molecular imaging of proteoglycan in cartilage, in which Gd(DTPA)₂³ distributes in cartilage in relation to the concentration of the charged glycosaminoglycan (GAG) molecules. Currently post-contrast (Gd-DTPA-go) spin-lattice relaxation time (T₁Gd) is used as dGEMRIC index to determine relative GAG levels within the joint cartilage. A recent study demonstrated that Δℝ1, i.e. the difference between the relaxation rates before (ℝ1pre) and after contrast administration (ℝ1post), showed a better correlation than either ℝ1pre or ℝ1post alone with biopsy determined GAG content in transplanted cartilage (1). On the other hand, in a separate study of native cartilage, a high correlation has been observed between T₁Gd and Δℝ1 (2), suggesting that either parameter could be used as dGEMRIC index. The purpose of this study was to evaluate if Δℝ1 compared to T₁Gd can provide better characterization of individual subjects as osteoarthritic (OA) or healthy.

MATERIALS & METHODS

Subjects: Thirty-one subjects, including 17 patients with OA (5 men and 12 women, aged 40-86, average age of 61.8 years) and 14 healthy volunteers (HS, 5 men and 9 women, aged 18-40, average age of 29.2 years) participated in this study. Imaging: Data were acquired on 1.5T GE Signa short bore twin speed system (GE Healthcare, Milwaukee, WI) using a commercial transmit/receive extremity coil. Pre- and 90 min post-contrast (0.2 mM/kg Gd-DTPA) T₁ measurements were performed. A two dimensional inversion recovery fast spin echo (2D IR-FSE) sequence and/or a three dimensional look locker (3D LL) sequence were used to measure T₁. The parameters of 2D IR-FSE sequence were TR=1.8s (2.2s for pre contrast), TE = 7.4 ms, Matrix = 384x384. TI=1.68, 0.65, 0.35, 0.15, 0.05s (2.9, 2.0, 1.0, 0.5, 0.1s for pre-contrast acquisition). Imaging parameters for 3D LL were: TR=2.2 s (2.8 s for pre contrast), TE=2 ms, flip angle=5°, τ = 5.693 ms, slices prescribed = 32, bandwidth = +/- 62.5 kHz, and matrix = 256x256. Eleven TIs ranged from 20 to 1839 ms (15 TIs ranged from 20 to 2568 ms for pre-contrast) were applied. Data analysis: Two ROIs for T₁ mapping were defined in the weight-bearing area of femoral and tibial cartilage, i.e. the central region of the femoral cartilage in medial condyle between the outer edges of the meniscus horns and entire tibial cartilage within the slice. T₁ mapping was performed with a custom software analysis routine written in MATLAB (The Mathworks; Natick, MA). Data correction for BMI was performed with a formula: T₁ (corrected) = T₁ (measured) + 3(BMI – 20). The averaged T₁ values of the two ROIs were used for data analysis. Δℝ1, ΔR₁T₁ and ΔR₁ (R₁Gd - R₁pre), were calculated with R₁Gd and R₁pre equal to 1/T₁Gd and 1/T₁pre. In order to test the effectiveness in separating OA and healthy subjects, a threshold for each parameter was determined based on its mean value (MEAN) and standard deviation (SD). For T₁Gd, the threshold was calculated by [(MEAN+SD)OA + (MEAN–SD)HS]/2. Regression analysis and t-test were used for statistical testing.

RESULTS

Compared to healthy subjects (HS), OA group had a slightly higher T₁pre (922 ± 76 vs. 859 ± 55, p=0.13), significantly higher ΔR₁ (1.31 ± 0.39 vs. 0.76 ± 0.21, p=3.53E-5), and significantly lower T₁Gd (425 ± 61 vs. 524 ± 48, p=2.22E-05). The OA/HS ratios were 1.07, 0.81, and 1.72 respectively (as shown in Figure 1), i.e. the differences between the two groups were 7%, 19%, and 72% respectively. But the SDs with ΔR₁ are much larger than those associated with T₁pre and T₁Gd. High correlation was observed between ΔR₁T₁ and ΔR₁, with R² of 0.93 (Figure 2). When using the calculated thresholds of 880 ms (T₁pre), 481 (T₁Gd), and 0.95 (ΔR₁), 21, 23, and 26 of the 31 cases respectively could be correctly identified as OA or HS (Figure 3).

DISCUSSION&CONCLUSION

The mean T₁pre in the OA group was higher than that for the HS group, probably related to the higher hydration in OA and is consistent with previous reports on T₁(3). Since the mean T₁pre is higher and mean T₁Gd is lower in the OA group, ΔR₁ is to be expected to show larger difference between group means for OA and HS (as shown in Figure 1). However, figure 3 shows that identification of individual subjects as OA or HS is only slightly better based on ΔR₁ compared to T₁Gd. Also figure 2 shows a high level of correlation between T₁Gd and ΔR₁ and so either of these parameters could be used as an index of dGEMRIC. In conclusion, we believe that in native cartilage (as opposed to cartilage implants where the hydration differences may be high) T₁Gd may be adequate for identifying individuals as OA or HS. However, as shown here, ΔR₁ does provide slightly better ability to distinguish subjects as OA or HS. The relatively modest improvement (given that the difference in mean values was significantly high, 72%) may be due to the higher standard deviation associated with ΔR₁ compared to T₁Gd. In practice, one has to also consider the logistics of additional effort and cost involved in acquiring T₁pre data.

REFERENCES