Effect of magnetization transfer on T1 and T2 measurements of articular cartilage

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Introduction

Recently, several qualitative magnetic resonance (MR) imaging techniques have been developed to detect early degeneration of articular cartilage (1, 2). Delayed gadolinium-enhanced MR imaging of cartilage (dGEMRIC) is a qualitative MR imaging technique that can evaluate the concentration of glycosaminoglycan (GAG) in cartilage (3). Transverse relaxation time (T2) mapping is an MR imaging technique that can evaluate the integrity of the collagen network structure and water content in cartilage (4). The dGEMRIC and T2 mapping technique require longitudinal relaxation time (T1) measurement and T2 measurement, respectively. Fast-spin-echo inversion-recovery (FSE-IR) sequence and multi-spin-echo (MSE) sequence have been commonly used for T1 measurement and T2 measurement of articular cartilage, respectively. However, it is known that undesirable factors, such as magnetization transfer (MT), can cause inaccuracy in T1 and T2 measurements, may be introduced when these sequences are used for multislice rather than single-slice acquisition (5). The aim of this study was to investigate inaccuracy of T1 and T2 measurements in cartilage when multislice acquisition is used.

Methods and Materials

A set of phantoms with different concentrations of collagen and contrast agent were used. Eight sets of collagen gel phantoms with concentrations of 0, 11, or 22% were prepared. The contrast agent Gd-DTPA2- (Magnevist; Schering, Berlin, Germany), was added into each set of the collagen gel phantoms to obtain a Gd-DTPA2- concentration of 0, 0.05, 0.1, 0.15, 0.2, 0.5, 1.0, or 1.5 milli-mol/L (mM).

A 3.0-Tesla MR imaging system (Trio; Siemens, Erlangen, Germany) with a knee coil was used for all measurements. T1 measurement was performed using an FSE-IR sequence. FSE-IR MR images were obtained using inversion times of 40, 80, 160, 320, 640, 1280, and 2560 msec. The FSE-IR imaging parameters were 2670 msec repetition time, 14 msec echo time, 150×150 mm field of view, 3.0 mm slice thickness, 5 number of slices, 512×512 matrix, 1 excitation, and 7 echo train length. T2 measurement was performed using an MSE sequence. MR images were obtained by using ten echo times of 10.3 to 103 msec. The MSE imaging parameters were 1500 msec repetition time, 150×150 mm field of view, 3.0 mm slice thickness, 5 number of slices 512×512 matrix, and 1 excitation. We investigated the difference in T1 and T2 values between that measured by single-slice and that measured by multislice acquisition.

Results

T1 in each slice as measured by multislice acquisition is shown in Figure 1. There was no obvious interslice variation in phantoms at a collagen concentration of 0%. On the other hand, interslice variation increased with an increase in collagen concentration. There was a nonsignificant tendency in T1 interslice variation to rise and fall regularly, with variation greater in odd slices and smaller in even slices.

T2 values in each slice as measured by multislice acquisition are shown in Figure 2. Across collagen gel concentrations, an apparent interslice variation observed in T1 measurements was not observed in T2 measurements.

Discussion

MT has been shown to be a significant contributor to image contrast in multislice MR imaging, and it is more significant in multislice FSE imaging because of the larger numbers of off-resonance radio-frequency pulses per TR period (6). The effect of MT on the relaxation measurement can be happen to any tissue, however, hyaline cartilage has been known to be sensitive to MT due to high collagen content and highly organized collagen structure (7). Thus, MT can affect relaxation time measurement of cartilage acquired with multislice MR imaging.

Based on the results of this study, we conclude that it will be difficult to adapt multislice acquisition for T1 measurement using FSE-IR methodology for clinical evaluation because of strong MT effects. On the other hand, multislice acquisition for T2 measurement using FSE is thought to be applicable for clinical evaluation.

Figure 1

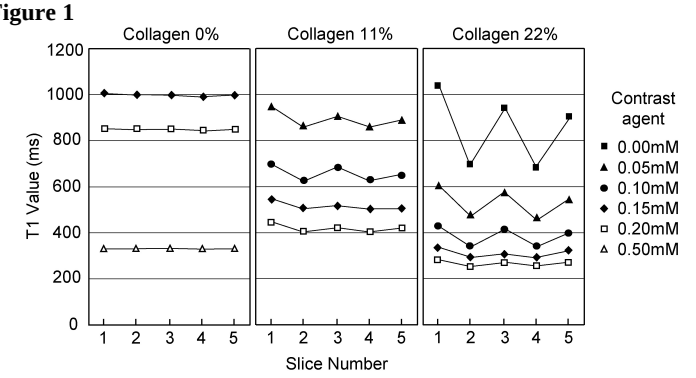

Figure 2

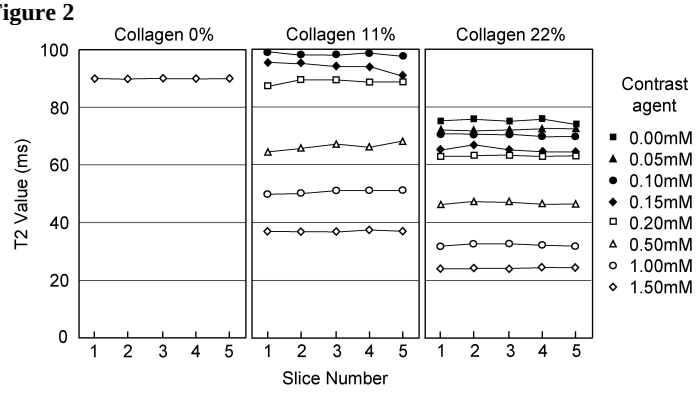

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Figure 1

T1 values in phantoms with each slice measured by multislice acquisition. There was no obvious interslice variation in phantoms at a collagen concentration of 0%; in contrast, interslice variation increased with an increase in collagen concentration. Interslice variation showed a tendency for T1 to rise and fall regularly, with longer values in odd slices and shorter values in even slices.

Figure 2

T2 values of phantoms with each slice measured by multislice acquisition. T2 values that exceeded expected values in our designed sequence were excluded. At all collagen gel concentrations, no apparent interslice variation was observed.