T2 Quantitation of Articular Cartilage at 1.5T

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In this study, we evaluate the accuracy of a multi-slice CPMG-based technique for T2 quantitation of articular cartilage at 1.5T. In vivo results are compared to multiple conventional Spin Echo acquisitions with a similar range of TEs. The stimulated echo component due to imperfect slice-selective refocusing pulses was large, and led to substantial inaccuracy in T2 calculation for articular cartilage in vivo.

Introduction

T2-mapping studies of articular cartilage at 7.0T have demonstrated a strong relationship between water T2 in cartilage and underlying collagen structure.[1,2,3] Because changes in collagen structure are believed to occur early in the progression of osteoarthritis, a method for creating T2 maps of articular cartilage at clinically relevant field strengths could prove valuable. While Spin Echo imaging with separate acquisitions for each echo time (TE) provides a standard for clinical T2 measurement, use of a multi-echo sequence would be desirable to reduce overall scan time. In this study, we evaluate the use of a multi-slice CPMG-based sequence for T2 quantitation of articular cartilage at 1.5T.

Methods

MR imaging was performed on a 1.5T GE Signa whole body system. A modified version of the GE product Fast Spin Echo (FSE) sequence was used to create separate images from each echo in the CPMG echo train. The crusher gradients in the FSE sequence are balanced to refocus the stimulated echo from imperfect 180degree pulses. In FSE imaging, this is desirable in order to maximize the SNR in the image. However, for quantitative T2 measurement, the second and later echoes contain a stimulated echo component that has the possibility of affecting the accuracy of T2 measurement. A longer refocusing pulse of 5.0ms duration optimized for slice profile was therefore compared with the standard 3.2ms duration pulse in order to assess if the stimulated echo contribution to the signal could be reduced. It has been suggested that excluding the first echo from a multi-slice CPMG sequence minimizes the error from stimulated echoes in calculated T2s for cartilage.[4] To test this theory, T2s were calculated for the multi-slice acquisitions (a) using all data points, and (b) excluding the first data point.

The multi-echo/multi-slice technique was compared to a series of images acquired using the conventional Spin Echo sequence. Axial images of patellar cartilage were acquired at four locations in a healthy volunteer using a 3" surface coil placed over the patella. A rectangular FOV with dimensions 14cm A/P (frequency direction) and 10cm L/R was acquired with frequency resolution = 256 and 96 phase encoding steps. A slice thickness of 2mm was used, with 2mm inter-slice spacing. TR was set equal to 1000ms for both sequences. For the multi-echo sequence, eight echoes were acquired with TEs equal to: 9.4ms, 18.7ms, 28.0ms, 37.4ms, 46.8ms, 56.1ms, 65.5ms, and 74.8ms for a total acquisition time of 3:20. For the Spin Echo series, images were acquired with TEs equal to: 13ms, 20ms, 35ms, 50ms and 80ms with an acquisition time of 1:40 per image.

A total of 10 regions of interest (ROIs) were defined in normal-appearing articular cartilage on the four slices corresponding to the first echo of the multi-echo series. These ROIs were copied over to the Spin Echo series for a direct comparison of measured T2s in the same regions. The mean signal intensity data from these regions was fit to a single exponential, and a value for the T2 was calculated from the fit.

Results

A comparison of the multi-echo sequence performance in a doped agarose phantom (T2=87ms; T1~700ms) with the product refocusing pulse (3.2ms) and with the 5.0ms refocusing pulse is shown in Table I. Significantly increased signal was observed in the second and later echo relative to the first echo, for both refocusing pulses. An improvement was noted for the longer refocusing pulse. Excluding the first echo from the calculation of T2 resulted in a similar value for T2 to what was obtained using the reference Spin Echo images.

Table I. T2 measurements for a multi-slice CPMG sequence in a doped agarose phantom.

Pulse Sequence	T2 (all echoes)	T2 (excl. 1st echo)
Spin Echo	87ms	
CPMG - 3.2ms pulse	102ms	89ms
CPMG – 5.0ms pulse	96ms	89ms

Typical decay data from a cartilage ROI is shown in Figure 1(a). The first echo is excluded from the CPMG data. The signal decay from the CPMG-based sequence includes a significant stimulated echo component for the second and later echoes, resulting in a prolonged decay and significant error in measured T2. Figure 1(b) shows a scatterplot of the T2 results for all 10 ROIs, and demonstrates well the error resulting from the stimulated echo component in the measured decay. Figure 2 shows the last echo in the SE (TE=80ms) and CPMG series (TE=74ms), and demonstrates the difference in image contrast due to the stimulated echo contribution. Note the bright fluid in the SE image in Figure 2(a).

Figure 1. (a) Semi-log plot showing typical signal decay for CPMG vs. Spin Echo images in a cartilage ROI. (b) Scatter plot of measured T2 for 10 ROIs in cartilage. The line is unity.

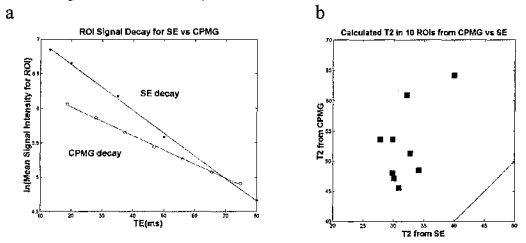
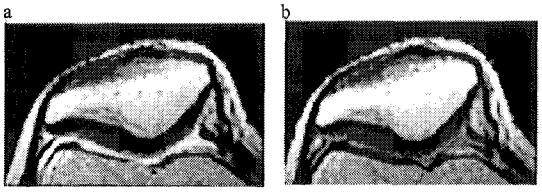


Figure 2. Images showing (a) Spin Echo contrast for TE=80ms and (b) multi-slice CPMG contrast for TE=74ms.



Discussion

Our study demonstrates that a multi-slice CPMG-based sequence, while potentially useful for qualitative assessment of articular cartilage, is not adequate for accurate quantitation of T2 values in this tissue. Although excluding the first echo resulted in accurate T2 values for an agarose phantom, this approach resulted in significant error for cartilage in vivo. As discussed previously, [5] including the stimulated echo component can result in a correct determination of T2 by coincidence when T2 and T1 are not significantly different. A more conservative approach using conventional spin echo with multiple acquisitions is therefore preferred for quantitative cartilage studies. Alternatively, a single-slice multi-echo technique that is optimized for minimization of the stimulated echo component[5] could be used.

References

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