Use of a Dual-Echo Fast-Spin-Echo Sequence for T2 Mapping of Cartilage within a Clinical Trial

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Introduction: It has been shown that T2 values in cartilage differ according to variations in macromolecular concentration, collagen orientation and structure, and tissue hydration. Thus, T2 mapping has become a common method for analyzing the quality of cartilage tissue using MRI. The relationship between the collagen content of cartilage and the associated T2 relaxation time of the tissue has been studied extensively[1-5]. Researchers have used various pulse sequences to obtain T2 maps, ranging from dual-echo sequences to multiple spin-echo sequences with varying echo times. Multiple-echo sequences have been shown to produce biased results due to the stimulated echoes that occur for each echo after the first echo. The goal of this paper is to show the applicability of a dual-echo fast-spin-echo sequence within a clinical trial for T2 mapping of cartilage. To be used in a clinical trial, the sequence needs to meet several criteria, including: relatively short imaging time, good resolution both in- and out-of-plane, ability to implement on a variety of hardware configurations, and capable of producing accurate T2 values for cartilage (in the range of 30-60ms).
Methods: Four test tubes containing 5, 10, 20 and 40 mM concentrations of $CuSO_4$ were prepared and T2 values were calculated from five single spin-echo sequences (TR/TE = 2000/11, 20, 40, 60, 80 ms). These values were taken as the ground truth. These same test tubes were attached to a volunteer subject's knee and imaged using a sagittal dual-echo fast-spin-echo sequence (TR=4600ms, TE=10, 60ms, thickness=2mm, FOV=14cmx14cm) as shown in Figure 1. The average signal intensities within the test tubes were calculated across seven slices of the collected images. From these values, the average T2 value within each test tube was calculated from the negative slope of the natural log of the intensities.
Results: The ground truth T2 values obtained from the five single spin-echo sequences were 30, 60, 121, and 231ms. The average T2 values for each test tube calculated from the dual-echo fast-spin-echo sequence were 28.46, 59.99, 96.33 and 162.55ms. Note that the calculated T2 values for the test tubes having expected T2 values of 30 and 60ms are very accurate (an error of 5% for the 30ms test tube and about 0.02% for the 60ms test tube). The errors are substantially larger for the longer T2-valued test tubes (an error of 20% for the 121ms test tube and 30% for the 231ms test tube).
Discussions and Conclusion: The results indicate that tissues with shorter T2 values can be calculated accurately using this dual-echo fast-spin echo sequence. The longer T2 values are underestimated due to reduced magnetization in the second echo. This is most likely a result of incomplete decay of transverse magnetization prior to the second RF pulse at 5ms, resulting in this magnetization being stored until the second pulse at 30ms and then dissipated in a stimulated echo at 35ms rather than contributing to the second spin echo. To reduce this effect and create accurate maps for longer T2 values, a longer first echo time could be chosen. This would decrease the signal-to-noise ratio in the images, thus reducing the accuracy of the calculated shorter T2 values. Therefore, the proposed dual-echo fast-spin-echo sequence is appropriate for mapping T2 values within the expected range (30-60ms).
References:

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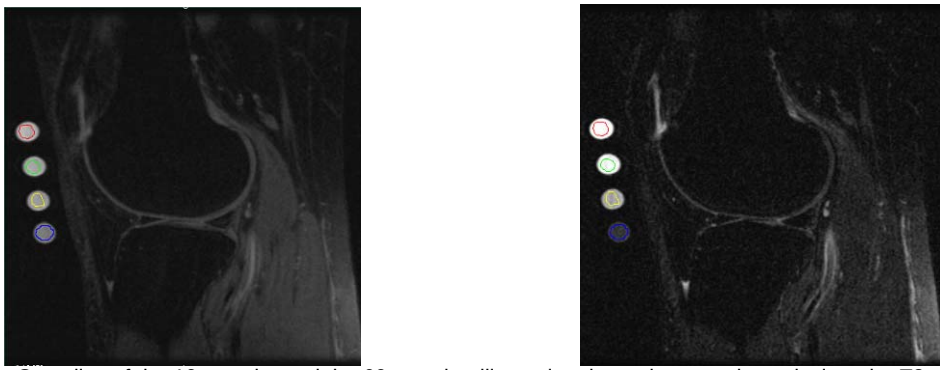

Figure 1 – One slice of the 10ms echo and the 60ms echo, illustrating the regions used to calculate the T2 values for the phantoms.