Quantitative T2* mapping of in vivo human meniscus using 2D duel echo radial sequence with minimal phase excitation pulse at 3 T

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Introduction

The human meniscus consists primarily of collagen fibers that contribute to important mechanical functions of the knee, such as load distribution, but is also strongly correlated with the progression of osteoarthritis (OA) [1]. Recently, several studies have demonstrated the ability of ultra-short echo time (UTE) sequence to target the rapid decay signal from the meniscus due to short T2 of the water in this highly collagenous structure [2]. Although our previous report indicated that 3D radial sequence with minimal phase excitation pulse is helpful in demonstration of in vivo meniscal architecture [3], relative long acquisition time restricts its clinical application. On the other hand, T2* relaxation time could reflect spin-spin interactions of protons bound to collagen and the degree of collagen fibril alignment [4]. Although UTE-T2* mapping has been used to target the short T2 components with increased sensitivity, Williams et al indicated that a UTE is not absolutely required to study meniscus T2* relaxation due to only low percentages of asymptomatic menisci showing T2* values less than 6.2 ms [5]. As a result, the purpose of this study is to design a 2D multi-slice dual echo radial sequence with a minimal phase excitation pulse for facilitating visualization of the fiber orientation in human meniscus based on quantitative T2* mapping.

Methods

To make sure the efficiency of the designed radial imaging sequence for yielding signal of the short T2 component, a phantom study was performed before in vivo human meniscus imaging. A combination of eraser array, water bottle and oil bottle was used to mimic the short T2 components of human meniscus and its surrounding tissues. After quality assurance of the phantom images, six asymptomatic volunteers (4 men and 2 women, aged from 25 to 32) without any known or suspected knee pathology were imaged in supine position at 3T MR system (TIM TRIO, Siemens Medical Solutions, Erlangen, Germany) with an eight-channel knee coil. More specifically, the 2D duel echo radial imaging method were repeated 4 times with 8 different echo times 0.82/2/3/4/6.95/8.13/9.13/10.13 ms, flip angle = 60^0, TR = 700ms, number of slice = 8, slice thickness = 5mm, projection number = 512, readout per projection = 512, in-plane resolution = 0.24×0.24 mm^2, acquisition time per repeat = 5 min 58 sec.

Results

The designed pulse sequence diagram is illustrated in Fig. 1. Results of the phantom study are shown in Fig. 2, in which images acquired before and after correction of ADC phase error as well as gradient delay are shown, respectively. Image homogeneity was significantly improved by the latter. Moreover, a sagittal image acquired from one of the subjects using the optimized radial imaging with a minimal phase excitation pulse and the derived T2* map are displayed in Fig. 3. The obtained image shows adequate signal from human menisci including both short T2 and long T2 components. In addition, the contrast between them is enhanced in the corresponding T2* map image, in which fibers with longer T2* relaxation time mainly running from the peripheral zone into the inner zone of meniscus. The T2* values of the menisci range from 4 to 8 ms, that is consistent with the previous report.

Discussion

The study illustrates the feasibility of combining 2D radial sampling with minimal phase excitation pulse to obtain adequate signal and achieve improved image quality for enhanced visualization of the fiber architecture in the human meniscus. The radial acquisition method provides a means to obtain high SNR from a substantially reduced echo acquisition time as well as dense sampling around the center of k-space, which allows calculating T2* map of in vivo human meniscus with higher accuracy. Our study also indicates the demonstration of the enhanced visualization of fiber orientation in T2* map than in the original images. To minimize artifacts caused by imperfect gradient performance, no ramp sampling was used in this study. In conclusion, our preliminary findings demonstrate that the proposed method allows enhanced visualization of structural details of the human meniscus, revealing the spatial T2* distribution and fiber orientation and may provide opportunities for diagnosing early degenerative changes for possible intervention.

Reference

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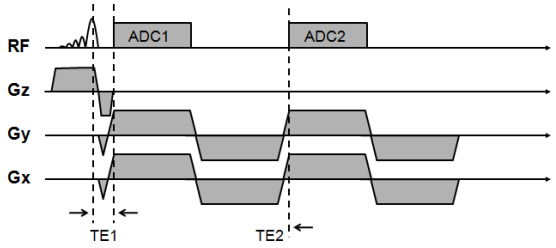

Figure 1 Illustration of pulse sequence used in this study.

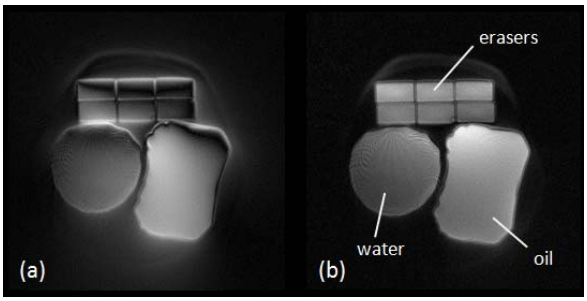

Figure 2 Phantom images acquired before (a) and after (b) correction of the proposed sequence.

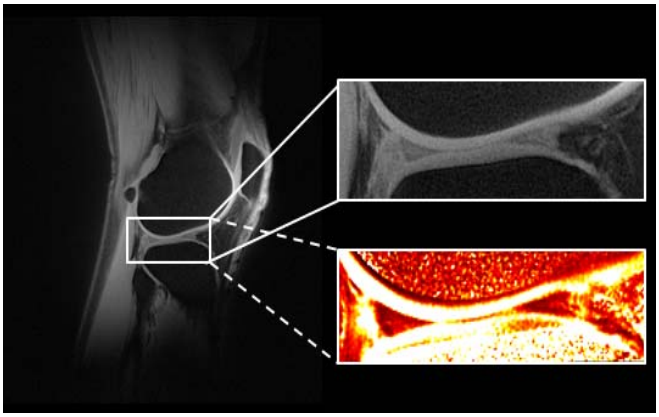

Figure 3 GRE images acquired with the modified dual echo radial sequence, enlarged meniscus image and the corresponding T2* map are shown on the right hand side.