Optimization of human meniscus imaging using minimal phase RF pulse

P-H. Tsai[1], H-W. Chung[1], and T-Y. Huang[2]

[1]Graduate Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan, [2]Department of Electrical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan

Introduction

Human meniscus is one of the important tissues related to the maintenance of the performance of knee joint, which plays a critical role in the normal biomechanics in load bearing, load distribution, and so forth [1]. Degeneration of human meniscus correlated strongly with the progression of osteoarthritis (OA) [2]. As a result, obtaining regional information of the menisci is helpful to clinical diagnosis and treatment. However, MR imaging of human meniscus is challenged by zonal heterogeneity due to variations in both fiber orientations and blood supply, as well as the short T2 value ranging from 5-8 msec at 1.5 T resulting from strong dipolar interaction in collagen molecules [3]. Ultra-short echo time (UTE) imaging provides a remedy to the latter issue [4], but the high signal intensity of menisci along with long-T2 suppression in UTE imaging does not provide clear distinction between the longer T2 and short T2 components. Therefore, the purpose of this study is to improve the zonal image contrast of human meniscus via imaging at moderately short TE using minimal phase RF pulse with optimized rephasing gradient.

Theory & Method

Minimal phase RF pulse is a non-linear phase pulse that could be designed using the SLR algorithm [5]. Although the phase dispersion could not be completely refocused, it is extremely suitable for acquisition of short T2 components with reduced echo time. The characteristics of minimal phase accumulation takes approximately 0.16 times of the slice selection gradient moment to rephase. In order to find the optimal percentage for the rephasing gradient, phantom study was performed by trimming the percentages to find the best image. The minimal phase RF pulse with the optimized rephasing gradient was then used for human imaging in vivo (Fig 1). Three normal volunteers were enrolled in this study, all imaged in a supine position at 3.0 T (TIM TRIO, Siemens medical solutions, Erlangen, Germany). These images were acquired with an eight-channel knee coil using modified fast gradient echo sequence with minimal phase RF pulse, TR = 732ms, TE = 2 ms (partial echo), number of slice = 12, slice thickness = 3mm, matrix size = 512×512, in-plane resolution = 0.29×0.29 mm^2, NEX = 4, acceleration factor = 2 , total acquisition time = 2m58s. Fat suppression was used for better contrast.

Results

The result of the phantom study was shown in Fig 2. The best image quality was shown empirically with 0.2 times of the slice selection gradient moment, which was close to but somewhat different from the estimation of previous report [5]. The quality of the other images gradually became worsened as the rephasing gradient moment deviated from the optimal value, which was a consequence when the RF excitation k-space trajectory passed through without stopping at the k-space origin. On the other hand, the image of human meniscus acquired by using minimal phase RF pulse with the optimal rephasing gradient was displayed in Fig 3. In addition to the increased SNR of the menisci, there exhibited better contrast between the longer T2 component and shorter T2 component in menisci (as indicated by black arrows in Fig 3).

Discussion

The present study indicated the feasibility of using minimal phase RF pulse with optimized rephasing gradient to obtain better regional contrast in the human menisci as a result of echo time optimization. Previous works reported that UTE sequence could provide the menisci with high signal intensity compared to conventional imaging. However, the trade-off includes the lengthened acquisition time from twice half RF excitation and the increased difficulty of image reconstruction duo to radial acquisition of non-Cartesian data, leading possibly to complicated artifacts in the presence of, e.g., off-resonance effects. In addition, the T2 relaxation time of human meniscus is not as short as other extremely short T2 tissues such as cortical bone. Hence, our preliminary finding demonstrated that the use of minimal phase RF pulse provides an easier option in the reduction of TE to a moderately short value, such that the zonal information of the menisci could be obtained at an improved contrast to investigate the variable constituents of collagen fibers during the progression of osteoarthritis.

Reference

1. Buma P, et al. Expert Rev Med Devices 2007;4:507-516
2. Rauscher I, et al. Radiology 2008 249:591-600
3. Robson M, et al. NMR Biomed 2006;19:765e80
4. Gatehouse PD, et al. Br J Radiol 2004;77:641-647
5. Pauly J, et al. IEEE Trans Med Ima 1991;10:53-65

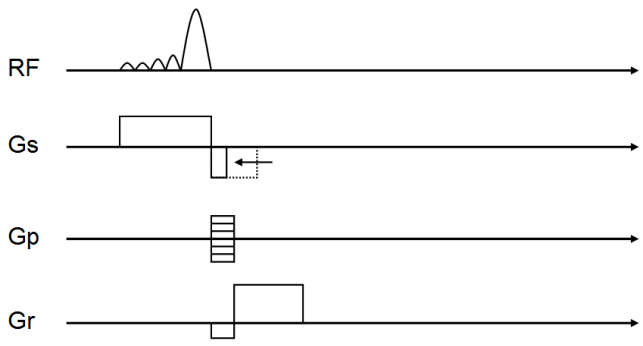

Figure 1 An illustration of pulse sequence used in this study.

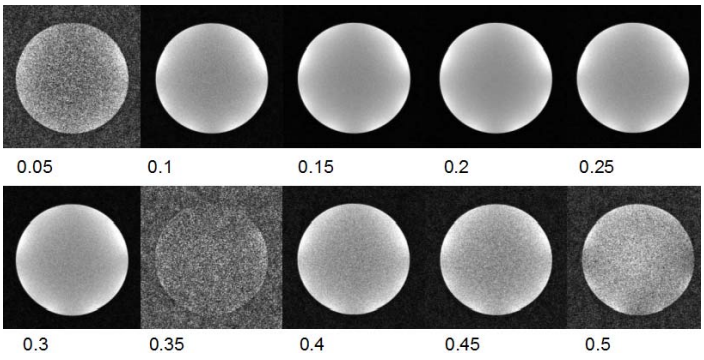

Figure 2 Different percentages of rephasing gradient applied in phantom study.

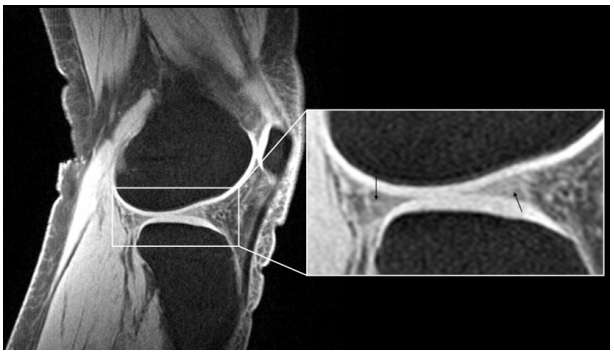

Figure 3 Image of human menisci acquired by minimal phase RF pulse with optimized rephasing gradient.