T1rho Imaging and Quantification of the Meniscus Using a T1rho-Prepared Ultrashort TE (T1rho-UTE) Sequence

J. Du[1], M. Carl[2], A. M. Takahashi[2], E. Diaz[1], C. B. Chung[1], E. Han[2], and G. M. Bydder[1]

[1]Radiology, University of California-San Diego, San Diego, CA, United States, [2]Global Applied Science Laboratory, GE Healthcare Technologies, Menlo Park, CA, United States

INTRODUCTION

Osteoarthritis (OA) is a multisystemic degenerative joint disease affecting not only articular cartilage, but also subchondral bone, synovium, the joint capsule and meniscii. Recently there has been increased interest in imaging and quantifying the impact of the disease on the meniscus (1-4). Krishnan et al. used delayed Gadolinium-enhanced MR imaging to investigate meniscal tissue degeneration (2). Rauscher et al. investigated T1ρ and T2 of meniscus and reported a significant correlation of these values with subject age, cartilage-derived parameters of disease and WOMAC scores (3). All these techniques are based on use of gradient echo or spin echo sequences with a TE of 4 ms or longer. Meniscii appear low signal on the morphological images of these types and accurate quantification may be challenging. Ultrashort TE (UTE) sequences with a TE of 100 μs or shorter provide higher signal intensity from the meniscus, and improved confidence in quantifying its short T2 species (4). Here we describe a UTE sequence designed to image and quantify T1ρ and T2* of the meniscus on a clinical 3T scanner.

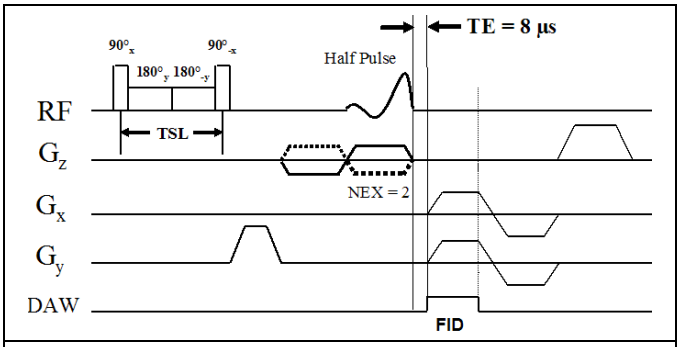

Fig 1 *UTE T1ρ sequence combines a regular UTE sequence (minimum TE = 8 μs) with a T1ρ preparation pulse, which consists of a hard 90° pulse followed by a spin locking field and another -90° hard pulse.*

MATERIALS AND METHODS

The UTE T1ρ sequence combines a 2D UTE sequence with a spin-lock preparation pulse, as shown in Figure 1. A minimal TE of 8 μs was achieved through the combination of half pulse excitation, radial ramp sampling and fast transmit/receive switching. The spin-lock pulse consists of a hard 90° to tip the spins to the transverse plane, followed by a spin locking pulse (B1ρ=12 μT, corresponding to 511 Hz) and another 90° pulse to tip the spins back to longitudinal axis. UTE acquisition starts after a series of spin-lock times (TSL) to detect the recovery of meniscal magnetization in the rotation frame (T1ρ). For comparison, meniscal T2* was measured using UTE acquisitions at progressively increasing TEs. Fat signal was suppressed for both the T1ρ and T2* measurements. The techniques were applied to 5 healthy volunteers with typical acquisition parameters as follows: FOV = 16 cm, TR = 500 ms, TSL = 0.2/1/5/25 ms (for T1ρ), TE = 0.2/1/5/25 ms (for T2*, here a longer TE of 0.2 ms was used for better eddy current control), bandwidth = ±62.5 kHz, readout = 512, slice thickness = 3 mm, 511 half projections, NEX = 2, 8.5 minutes for each scan. Furthermore, T1rho dispersion was investigated by varying the spin locking field (6, 12 and 20 μT) with three TSL values (0.2/5/20 ms) to save scan time. T1ρ was derived through exponential fitting of the following equation: $S(TSL) \propto \exp(-TSL/T1\rho)*(1-\exp(-(TR-TSL)/T1))/(1-\exp(-TSL/T1\rho)*(\exp(-(TR-TSL)/T1))))$, which accounts for T1 relaxation effects since we used a relatively short TR of 500 ms (1). T2* was derived through exponential fitting of the equation: $S(TE) \propto \exp(-TE/T2*)$.

RESULTS AND DISCUSSION

Figure 2 shows sagittal fat-saturated UTE T1ρ and T2* images of the knee joint of a 31 year old healthy male volunteer. Both the articular cartilage and meniscus are depicted with high signal and high contrast. Excellent exponential curve fitting was achieved for both T1ρ and T2* (Figure 3), e.g., short T1ρ values of 8.2 ms and short T2* values of 4 ms were demonstrated. There is significant T1rho dispersion, with T1ρ increasing from 6.9 ms with B1ρ of 6 μT to 12.9 ms with B1ρ of 20 μT. Meanwhile, T1ρ of the cartilage was measured to be around 34 ms which is in consistent with published values and indirectly helped validate our UTE T1ρ technique (1, 3). In the future we will further validate the UTE T1rho technique and investigate the T1rho dispersion which may be particularly important for short T2 species since it may provide information on bound water and bulk water which have different responses to the spin locking field (5).

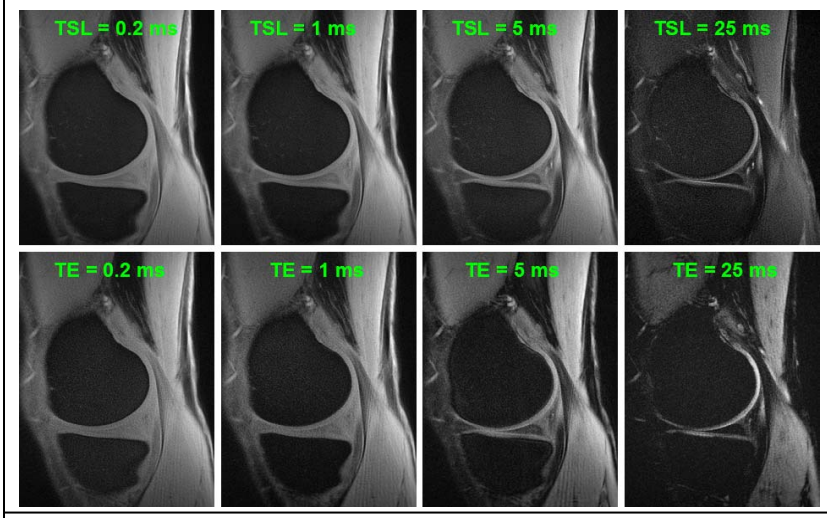

Fig 2 *Fat suppressed sagittal UTE T1ρ (1st row) and T2* (2nd row) images of a 31 year old healthy volunteer show excellent depiction of the cartilage and meniscus.*

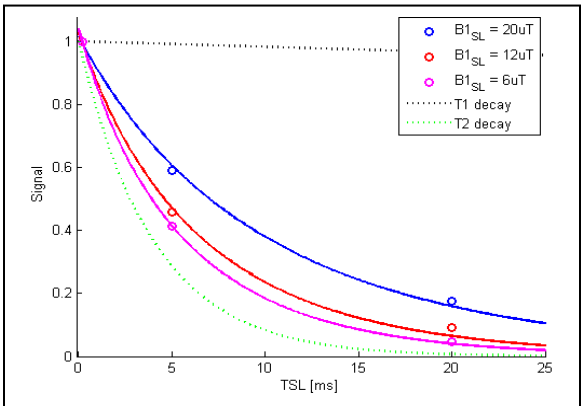

Fig 3 *Fitted T1ρ curves at three spin locking fields, as well as the fitted T2* and T1 decay curve. Meniscus of this volunteer has a short T2* of 4 ms, T1 of 584 ms, and T1ρ of 6.9, 8.2 and 12.9 ms under a spin locking field B1ρ of 6, 12 and 20 μT. The T1ρ dispersion is quite significant for meniscus.*

CONCLUSIONS

High quality T1ρ and T2* images of the meniscus can be achieved with UTE sequences combined with spin locking preparation pulses or variable TE approaches. The high signal from meniscus provides improved confidence in morphological and quantitative evaluation of meniscus with its short T2.

REFERENCES

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