Spectroscopic Imaging of the Knee Using an Interleaved Ultrashort TE (UTE) Sequence

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INTRODUCTION

The human knee contains several tissues with short T2 relaxation times, such as menisci, tendon, and the deep radial and calcified layers of cartilage (1, 2). Ultrashort TE (UTE) sequences have been used to image these tissues with high signal and contrast (2). It would be very useful to get information about the spectral composition of these short T2 tissues. UTE-CSI based on a variable TE Cartesian acquisition has been reported (3, 4). Here we report a novel technique for high spatial resolution spectroscopic imaging of the short T2 tissues in the knee utilizing multi-echo variable TE UTE acquisitions with fat suppression using a long adiabatic 90^0 pulse and dephasing.

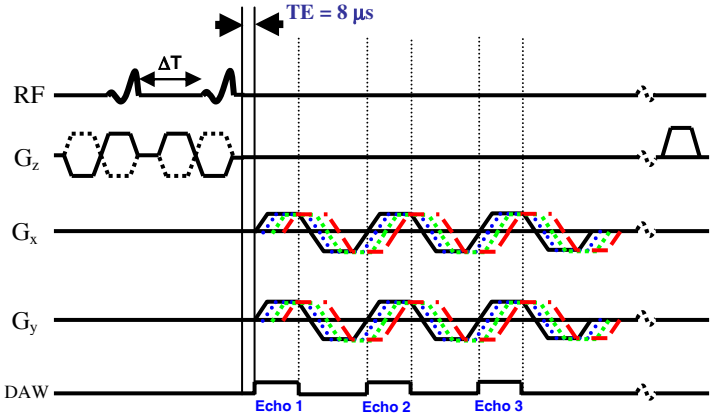

Figure 1. Multi-echo variable TE UTE sequence for knee spectroscopic imaging. Fat signal is suppressed using a long adiabatic 90^0 pulse and dephasing (not shown). Double half pulse (with separation ΔT) excitation was used to reduce out-of-slice contamination (improve the slice profile), and was followed by multi-echo radial ramp sampling. The projections were interleaved into multiple groups with each group having a different TE. Delay time and echo spacing were chosen so that TEs were uniformly distributed for the interleaved groups.

MATERIALS AND METHODS

A multiecho multi-slice variable TE UTE sequence combined with long T2 suppression (Figure 1) was implemented on a 3T Signa TwinSpeed scanner (GE Healthcare Technologies, Milwaukee, WI) with a maximum gradient performance of 40 mT/m and 150 mT/m/ms. Fat signal was suppressed using a long adiabatic 90^0 pulse (26 ms duration) and dephasing to help reduce long T2 fat signal without saturating the short T2 water signals (5). Double half pulses were used to improve the slice profile by reducing their out-of-slice contamination (6). A total number of 1980 projections were sampled, and interleaved into 36 groups with each group having a different TE (TE delay interval = 140 µs). Each interleaved group of projections was used to generate one image. Two techniques were integrated into the reconstruction algorithm: (1), view sharing of high spatial frequency projection data from neighboring groups to suppress streak artifacts; (2), sliding window reconstruction which was used to reconstruct images for each interleaved group or TE. Other acquisition parameters include: FOV = 16 cm, TR = 150 to 200 ms, TE = 8 µs, 4 echoes, echo spacing = 5.0 ms, flip angle = 80°, BW = 61.25 kHz, readout = 512, number of slices = 5 to 8, slice thickness = 3 mm, scan time = 10 to 13 minutes.

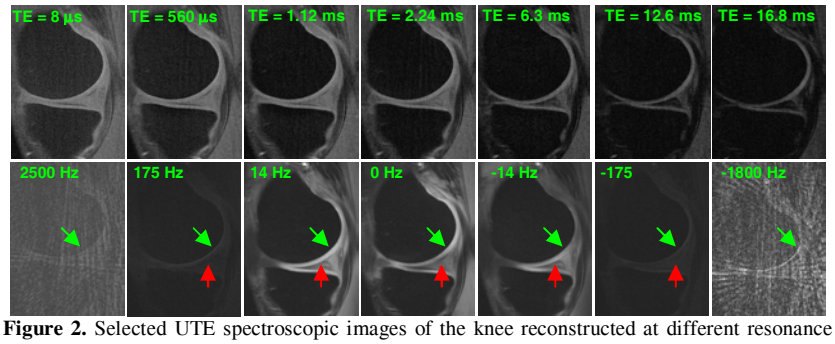

Figure 2. Selected UTE spectroscopic images of the knee reconstructed at different resonance frequencies relative to water. The calcified layer (green arrows) and menisci (red arrow) are well depicted across a broad spectrum range, consistent with their short T2 values. The acquired pixel size is 0.31×0.31×3.0 mm^2, with a spectral bandwidth of 7.1 kHz, and spectral resolution of 7 Hz (after zero-filling). The first and last images were re-scaled to show the strong streak artifacts, which were shifted to high frequencies because of the interleaved acquisition.

RESULTS AND DISCUSSION

Figure 2 shows the UTE spectroscopic images of the knee at different resonance frequencies relative to water. The deep radial and calcified layers of cartilage and menisci are clearly demonstrated across a broad spectrum of frequencies, consistent with their short T2 values. Spectra from a single pixel from the calcified layer and a meniscus are depicted in Figure 3. The spectral of the calcified layer cartilage is shifted by 28 Hz from that of meniscus, probably due to greater diamagnetic susceptibility of the calcified layer cartilage (7). Future work will focus on multi-echo spin echo UTE spectroscopic imaging to provide more echoes and improve spectral resolution.

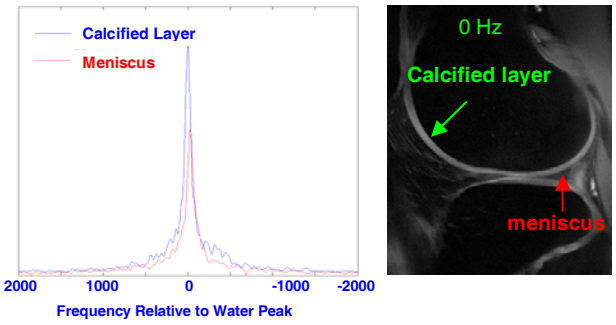

Figure 3. UTE spectra (left) for a single pixel from the calcified layer (green arrow) and a meniscus (red arrow). There is a slight shift of 28 Hz between the two peaks, probably due to greater diamagnetic susceptibility of the calcified layer cartilage.

CONCLUSIONS

Multi-slice UTE spectroscopic imaging appears to be a useful technique for demonstrating spectral composition of the short T2 components in the knee.

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