Ultrashort TE (UTE) Spectroscopic Imaging of Cortical Bone Using a Variable TE Acquisition and Sliding Window Reconstruction

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INTRODUCTION

Cortical bone in the mature skeleton has a very short T2 (200 to 500 μs), and produces no detectable signal with conventional pulse sequences. With ultrashort TE (UTE) sequences with echo times of 80 μs, cortical bone signal is detectable (1). Here we propose a UTE spectroscopic imaging technique based on a dual echo, variable TE approach (2, 3). Long T2 signals from muscle and bone marrow are suppressed using long adiabatic 90^0 pulses and dephasing or inversion pulses and nulling. A view sharing and sliding window reconstruction algorithm is implemented to reconstruct images at different TEs, followed by Fourier transform in the time domain to generate bone spectroscopic images.

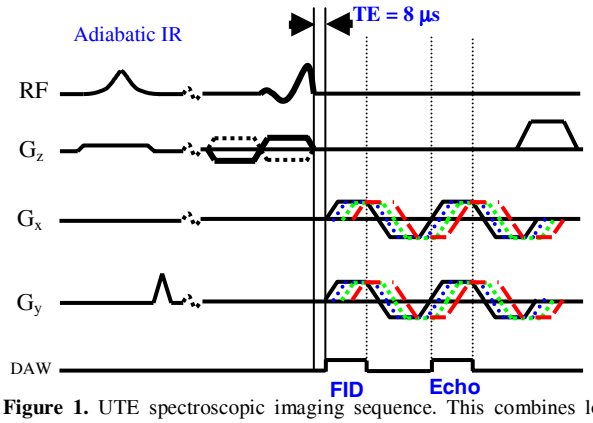

Figure 1. UTE spectroscopic imaging sequence. This combines long T2 suppression, half pulse excitation and variable TE radial ramp sampling.

MATERIALS AND METHODS

The UTE spectroscopic imaging sequence was implemented (Figure 1). A dual echo, variable TE UTE acquisition was preceded by a long T2 suppression of signals from muscle and fat using a long adiabatic inversion pulse. The whole set of projections was interleaved into multiple groups, with each group at a different TE delay to uniformly cover the k-space. Images corresponding to each TE were reconstructed from each group of projections using view sharing of high spatial frequencies from neighboring groups (Figure 2). A 3-inch coil was used for signal reception. The acquisition parameters were: FOV = 10 cm, TR = 300 ms, TI = 125 ms, TE = 8 μs, flip angle = 80°, BW = 61.25 kHz, readout = 256, projections = 2025 (interleaved into 45 groups with TE delay of 80 μs per interleave), slice thickness = 8 mm, scan time = 20 min.

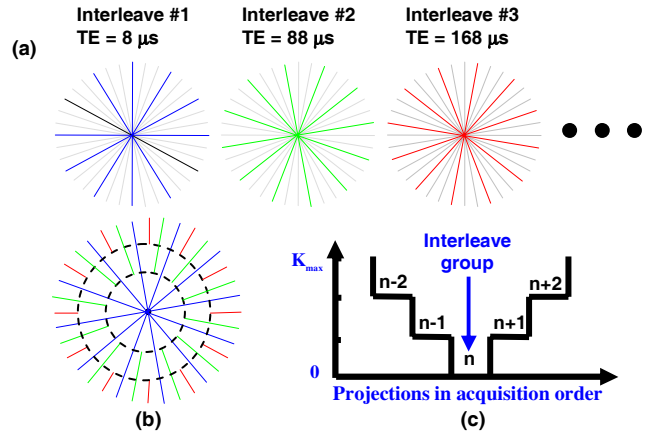

Figure 2. Sliding window reconstruction algorithm for UTE spectroscopic imaging: (a) each group of projections uniformly cover k-space, with TE successively delayed by 80 μs; (b) high frequency data is shared among neighbor groups; (c) sliding window is used to recon each TE image.

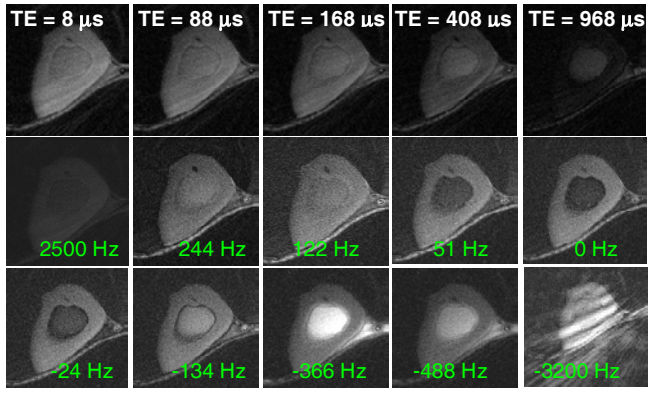

Figure 3. Selected UTE variable TE images (upper row) and spectroscopic images reconstructed at different frequencies relative to water (lower rows) with high resolution (0.39×0.39 mm^2) and broad spectral bandwidth (12.5 kHz). Cortical bone signal is bright over a broad range of the spectrum. Oscillating streak artifacts in time domain are shifted to high frequencies in the spectral domain (last image is rescaled to better show the artifact), resulting in almost streak artifact free images around the water peak.

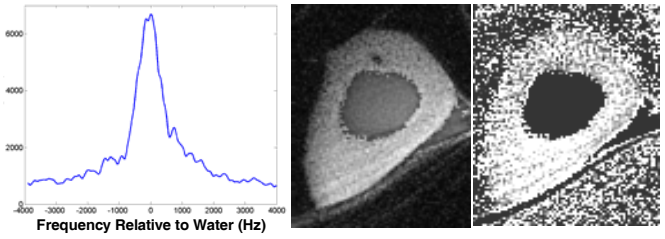

Figure 4. UTE spectrum of a single pixel from the cortical bone (left), relative water distribution (middle), and R_2* map (right). Relative water content was calculated as the water peak area by fitting each spectrum as a Gaussian shape. T2* values were fitted using MRUI tool in the image domain, and ranged from 300 μs to 600 μs. There are some streak artifacts in the R2* map, which may be better tolerated in spectral domain where the streak artifacts were shifted to high frequencies relative to the water peak.

RESULTS AND DISCUSSION

Figure 3 shows UTE spectroscopic images corresponding to different resonance frequencies relative to water. The spectrum for a single pixel is displayed in Figure 4, as well as the relative water distribution, which is the integral of the water peak area. Absolute quantification of bone water fraction requires a reference sample (4). Total scan time can be reduced by reducing the spectral coverage (fewer images with larger TE delay).

CONCLUSIONS

High resolution UTE spectroscopic imaging of the cortical bone is possible using variable TE UTE acquisition with long T2 suppression.

REFERENCES

1. Reichert I. et al. MRI 2005; 23:611-618.
2. Gold GE, et al. Magn Reson Med 1995; 34:647-654.
3. Song HK. et al. Magn Reson Med. 2004; 52:815-824.
4. Techawiboonwong A, *et al*., Proc. ISMRM, 2006, P3620.