Ultrashort TE (UTE) Imaging of the Cortical Bone at 3T

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INTRODUCTION

Conventional magnetic resonance sequences produce a signal void for species with very short T2s, such as cortical bone which has a T2 = 200-500 µs depending on field strength (1, 2). One method for detecting bone signal is to use ultrashort echo time (UTE) pulse sequences where TE can be reduced to below 100 µs (2, 3). By combining half pulse excitation, radial ramp sampling, and fast transmit receiver switching, an ultrashort TE of 8 µs can be achieved. Cortical bone contains about 15-18% free water by volume (4), providing a mobile proton density far below that of muscle and fat. In order to optimize the conspicuity of bone, the dynamic range can be maximized by efficient suppression of the long T2 fat and muscle signals (5-7). Here we present a technique for cortical bone imaging using a dual echo UTE sequence combined with two different long T2 suppression approaches: long adiabatic 90^0 pulse followed by gradient de-phasing and long adiabatic inversion pulse with TI properly chosen to suppress fat and muscle simultaneously.

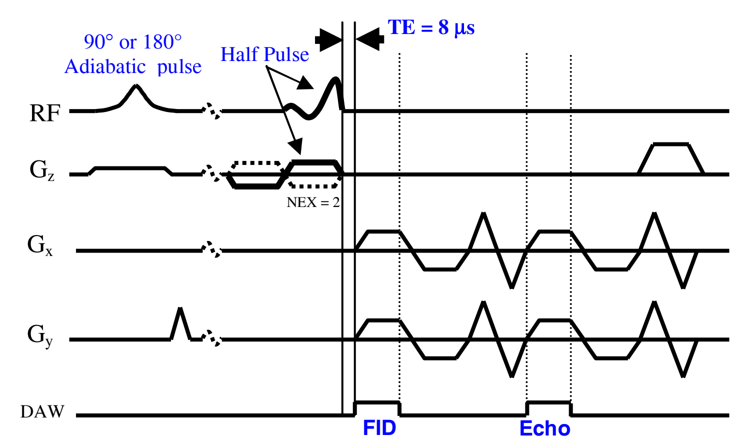

Figure 1. UTE pulse sequence diagram for cortical bone imaging. A long adiabatic 90^0 or inversion pulse was followed by a crusher gradient to suppress long T2 signals, mainly bone marrow fat and muscle, which was further suppressed through a dual echo UTE acquisition followed by echo subtraction.

MATERIALS AND METHODS

The dual echo UTE sequence (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. A long adiabatic 90^0 pulse (26 ms long) or inversion pulse (17 ms long) was played first, followed by a large crusher gradient to completely spoil in-plane magnetization. Then a short half pulse excitation was followed by radial ramp sampling for data acquisition. A 3-inch coil was used for signal reception. The acquisition parameters for the 90^0 approach were: FOV = 10 cm, TR = 75 ms, TE = 8 µs, 2 echoes, echo spacing = 5 ms, flip angle = 80°, BW = 61.25 kHz, readout = 512 (actual sampling points = 284), number of projections = 511, slice thickness = 8 mm, NEX = 12, scan time = 5 min. In the inversion recovery approach, NEX = 2, TR (=300ms) and TI (=125 ms) were chosen so that both fat and muscle were suppressed simultaneously. Other imaging parameters were the same as that for the 90^0 approach.

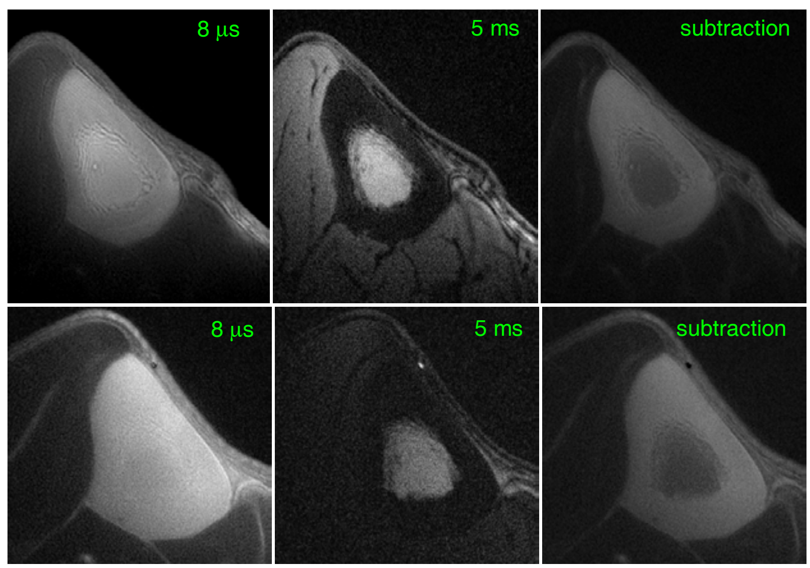

Figure 2. Dual echo cortical bone images acquired with UTE sequence combined with long T2 suppression using adiabatic 90^0 (upper row) and adiabatic inversion (lower row) pulses. Cortical bone signals appear bright in the first echo, and dark in the second echo. Echo subtraction suppresses the residual fat and muscle signals, providing high contrast between cortical bone and fat/muscle. The imaging FOV = 10 cm, readout matrix = 512×511, producing an acquisition pixel size of 195×195 μm^2 under a total scan time of 5 minutes.

RESULTS AND DISCUSSION

Figure 2 shows dual echo images of cortical bone for both 90^0 (upper row) and inversion recovery (lower row) approaches. The cortical bone was depicted with high in-plane spatial resolution of 0.195×0.195 mm^2, and high contrast over the bone marrow fat and muscle. There are some residual fat signals in the bone marrow in the first echo, which is significantly suppressed through echo subtraction. SNR efficiency, defined as SNR over the square root of scan time, is similar for both approaches. Due to the non-ideal slice profile, inversion recovery approach typically requires a 100% gap for multi-slice imaging (8). The 90^0 approach is more robust for multi-slice imaging of the cortical bone.

CONCLUSIONS

The dual echo UTE sequence combined with long adiabatic 90^0 or adiabatic inversion pulse is an effective method to image cortical bone with high SNR and high contrast in a relatively short scan time of 5 minutes.

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