Ultrashort Echo Time Imaging of Cortical Bone at 7 Tesla Field Strength

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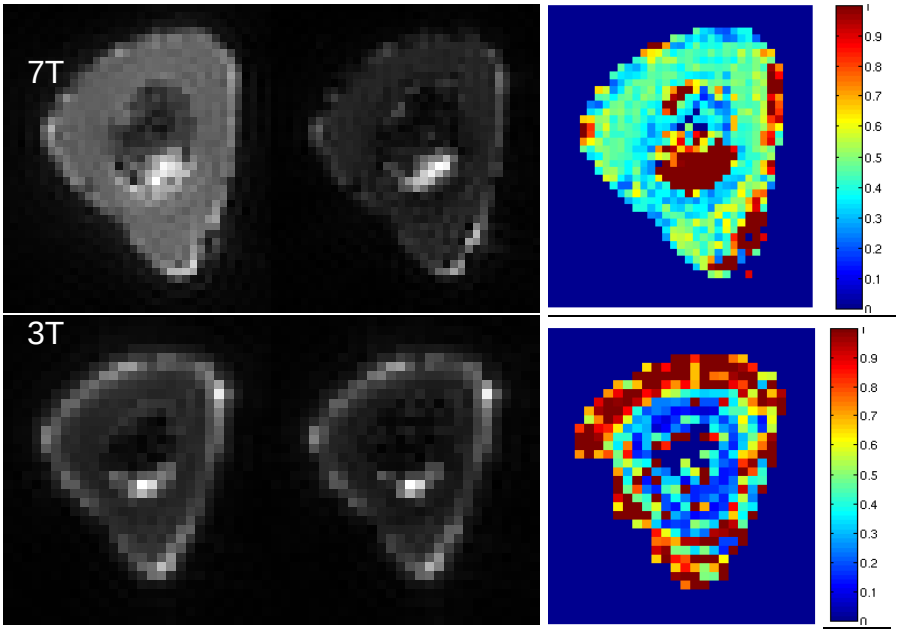
Introduction

MRI at ultra-high field (UHF) strength of 7 Tesla has been increasingly used and optimized for *in vivo* applications over the past few years. In particular, the increased signal to noise ratio (SNR) renders this new modality very attractive for imaging soft tissues in the human body. More solid or semi-solid tissues such as trabecular and cortical bone provide little to no signal in conventional MRI scans. This is because their signal has decayed to almost zero by the time the data is acquired. However, by using advanced MR imaging techniques like short radiofrequency pulses and a radial readout (1), the echo time TE can be considerably shortened. In this study, we have implemented a 3D ultra-short TE sequence on a 7T and 3T MR scanner and compared its performance using mid-diaphysial sections of three fresh cadaveric radii specimen. Cortical bone possesses extremely short transverse relaxation times of less than 500 μsec (2). Previously, ultra-short TE (UTE) of cortical bone was performed at 1.5T (3) and more recently at 3T (4). In this study, we investigated the feasibility of 3D UTE on a 7T human MR scanner. In order to compare the performance objectively, we have also built two small identical RF coils for both field strengths. In this feasibility study, we hypothesized that UTE is possible at 7T field strength and provides a significant increase in SNR and that T2 relaxation time might differ between the field strengths.



Images acquired at different TE (64μs and 256μs are shown) along with a T2 map (right).

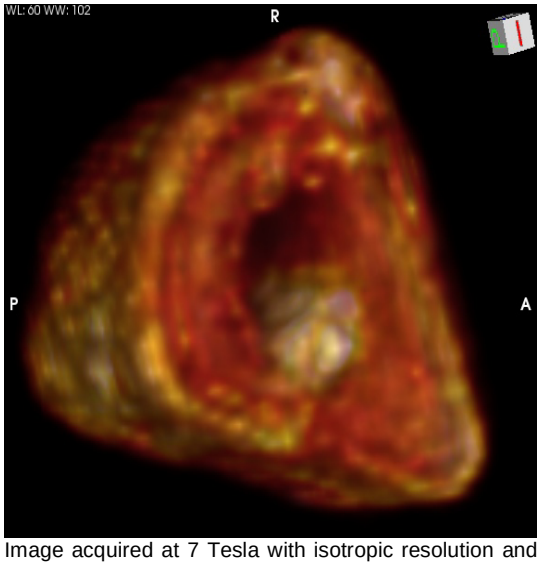


Image acquired at 7 Tesla with isotropic resolution and 3D volume rendered. The cortical shell is clearly depicted (red). Residual tissue with long T2 is shown in yellow and white

Material and Methods

Mid-diaphysial sections of three fresh cadaveric radii were used for UTE imaging, performed on a 7T and 3T Signa MRI systems (General Electric, Milwaukee, WI) with a gradient system of maximum amplitude of 40 mT/m and 150 mT/m/msec of slew rate. Transmit gain and shimming were manually adjusted. To operate at high frequency with high efficiency, two coaxial transmission-line saddle RF coils were built for each field strength. The two coils had the same size of 57mm in diameter and 57mm in length for a meaningful performance comparison at the two field strengths. For UTE imaging, a 3D pulse sequence was developed and implemented on both systems. In order to shorten the acquisition time, UTE uses trajectories that begin at the center of k-space. With this technique, the echo time is considerably shortened and there is no need for any prephasing gradients, which would increase the minimum TE. These center-out radial trajectories achieve the best possible resolution in the shortest acquisition window. Furthermore, the data is acquired on the gradient ramp, minimizing further TE. For 3D UTE imaging, a constant amplitude RF pulse can be applied. This rectangular pulse excites the entire imaging volume and thus requires no gradients. The hard pulse performed with the maximum amplitude to best excite short-T2 components. Applying these techniques, a minimum TE of 64 μs could be achieved at both field strengths. Further imaging parameters included: Repetition time TR = 25 ms, 1 mm isotropic resolution, 6x6x6 cm FOV, excitation angle α=15° and 600 μs readout duration.

Results and Discussion

We found a significant increase in SNR at 7T compared to 3T (factor of 2) but no significant difference in T2 values between the field strengths (200μs-600μs at both field strengths). We concluded that UHF MRI at 7T has great potential for imaging tissues with short T2. This is primarily due to the significant increase in SNR at the higher field strength. This technique could provide surrogate measures of cortical bone composition which would be important clinical endpoints for bone quality assessment.

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