Dual Echo UTE Imaging with Rescaled Subtraction (dUTE-RS): Scaling Factor Optimization Study

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Introduction

Ultra-short TE (UTE) imaging that uses TEs from typical values of several milliseconds for clinical sequences to tens of microseconds or less is developed for directly visualizing short T2 components [1]. However, long T2 signals, such as muscle and fat signals, are always existed in the typical UTE images which suppress the short T2 tissue signals. There are many long T2 suppression techniques, such as long T2 species saturation, inversion recovery method [2, 3]. The most efficient and simple way is dual echo acquisition with images subtraction. UTE with rescaled subtraction (UTE-RS) was put forward instead of directly subtraction to improve cortical bone contrast significantly [4]. However, only a few scaling factors were used to detect the image contrast difference. Optimal scaling factor is need for obtaining the best contrast of cortical bone.

Materials and Methods

A dual echo 2D UTE sequence with a minimum TE of 10μs was implemented on a clinical 3T scanner. Short T2 signal from cortical bone is almost completely decayed by the second echo, while long T2 signals from muscle and fat experience much less decay. Due to the large difference in T_1 values between fat (~360ms) and muscle (~1400ms) at 3T, directly two echo images subtraction may still yield strong residual signal from muscle or fat, compromising the image contrast for cortical bone. In dUTE-RS, the FID image was scaled down (with different scaling factor from 0 to 1) relative to that of the second image so that signals from muscle and fat can become lower than those from the second image. In the subtraction images negative signal intensity is allowed so that signals from muscle/fat are negative while cortical bone still has positive contrast. The dUTE-RS technique was applied to tibia imaging of three healthy volunteers. The study was approved by the local institutional review board and informed consent was obtained from subject before scan. Typical acquisition parameters included: FOV=15cm, TR=300ms, TE=10μs/4.4ms, FA=60°, bandwidth= ±62.5kHz, slice thickness=8 mm, NEX=2, matrix=512×512, 805 half projections for each image satisfying Nyquist theorem. The signal-decay ratios of cortical bone, muscle and marrow between first and second images were calculated by measuring the signal from the corresponding areas. The contrast between cortical bone and marrow ($Contrast_{Cortical\_Marrow}$) and muscle ($Contrast_{Cortical\_Muscle}$) were calculated as formula (1.1). S_i^1 is the signal of tissue i in the first image and αis scaling factor.

$$Contrast_{i\_j} = \left(\alpha S_i^1 - S_i^2\right) - \left(\alpha S_j^1 - S_j^2\right) \quad (1.1)$$

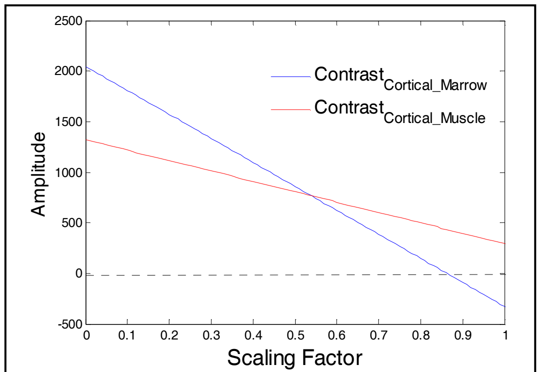

Fig. 1 $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ vary with different scaling factor in rescaled subtraction image.

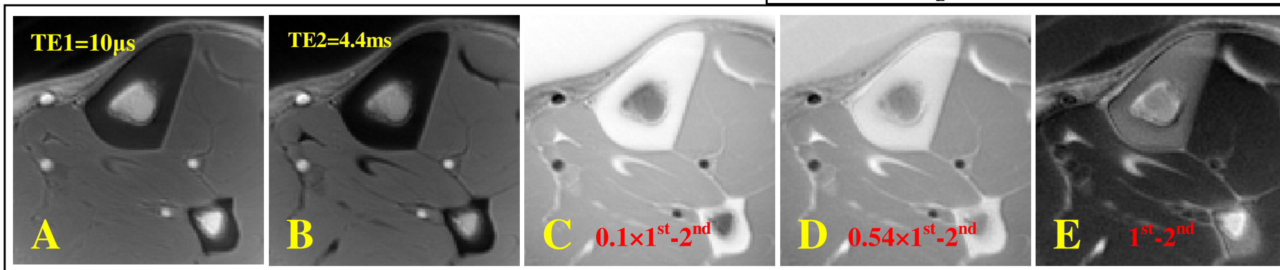

Fig. 2 Dual echo UTE imaging of the tibia of a volunteer with a TE of 10μs (A) and 4.4 ms (B). High cortical bone contrast with surrounding tissue with rescale factor of 0.1 (C). Nearly equal $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ are obtained with the factor of 0.54 (D). Conventional echo subtraction with factor of 1 (E) produces negative $Contrast_{Cortical\_Marrow}$.

Results and Discussions

The signal intensity differences between two images are 30.3±3.2% for cortical bone, 90.1±1.3% for muscle and 74.4±3.3% for marrow. It means that these three tissues have independent decay character and not significant difference among subjects. $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ vary with different scaling factor in rescaled subtraction image and absolute pixel intensity rescaled subtraction image are shown in Fig.1, respectively. As Fig.1 shows, small scaling factors induce high contrast value of $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ and low contrast appears in direct subtraction image. Negative value of $Contrast_{Cortical\_Marrow}$ in Fig. 1 means cortical bone signal suppression by marrow signal. Nearly equal $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ values are obtained when scaling factor is 0.5. Fig. 2 shows axial UTE imaging of the tibia of a healthy volunteer. Cortical bone is barely visible in the dual echo images. Rescaled subtraction image provide high contrast of cortical bone with small factors. Conventional echo subtraction provides poor contrast between bone and marrow.

Conclusions

Fig. 1 presents the feasibility of rescaled subtraction method in dual echo UTE imaging. Direct subtraction image cannot provide good contrast between cortical bone and surrounding tissue. Due to the image intensity is scan parameters dependent, the value of $Contrast_{Cortical\_Marrow}$ and $Contrast_{Cortical\_Muscle}$ in Fig. 1 will be different in distinct scan. Using low scaling factor in rescaled subtraction makes most tissues with negative values, which not reflect the real intensity. Future work will focus on the contrast measurements for each scaling factor and collect more subjects.

[1] Gatehouse PD, *et al*., Clinical Radiology, 2003; 58:1-19. [2] Larson PE, *et al*., MRM 2006; 56:94-103. [3] Reichert Ines LH, et al., MRI 2005; 23:611-618. [4] Du J, et al., MRI 2011; 29: 470-482.