Ultrashort TE Imaging with Rescaled Digital Subtraction (UTE RDS)

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INTRODUCTION

Imaging of short T2 tissues often requires not only a short TE so that signal from very short T2 species can be detected, but efficient suppression of the signal from surrounding long T2 species which may have much higher MR signals (1-4). There are three major long T2 suppression techniques: 1) A long 90° pulse followed by gradient spoiling to selectively saturate long T2 species (1). This approach is sensitive to B1 and B0 inhomogeneity. 2) A long adiabatic inversion pulse to invert and null long T2 species (2, 3). This approach is insensitive to B1 inhomogeneity but difficult for multi-slice imaging. 3) Dual echo acquisition and subtraction (2, 4). This approach is simple and effective in many cases, such as 3D tendon imaging. However, the short T2 contrast may be significantly reduced with high resolution imaging due to increased echo spacing and susceptibility effect, as well as reduced proton density as in the case of imaging of cortical bone which has much lower proton density than muscle and fat. Here we present a technique called UTE with Rescaled Digital Subtraction (UTE-RDS) which provide high positive contrast for multi-slice 2D imaging of short T2 species using a clinical 3T scanner.

MATERIALS AND METHODS

A dual echo multi-slice 2D UTE sequence with a minimum TE of 8 µs was implemented on a clinical 3T scanner. TE for the second echo was kept at the minimal value for the fat and water in-phase imaging, i.e., 4.4 ms or 6.6 ms depending on the FOV, acquisition matrix size and bandwidth. Short T2 signals from cortical bone and tendons are almost completely decayed by the second echo, while long T2 signals from muscle and fat experience much less decay. However, simple echo subtraction may still yield strong residual signal from muscle or fat, compromising the image contrast for cortical bone or tendons. In UTE RDS, the first echo was scaled down so that signals from muscle and fat were lower than those from the second echo. In the subtraction images negative signal intensity is allowed so that signals from muscle/fat are negative while bone/tendons still have positive contrast, separating them from air or background which have negative values. The UTE RDS technique was applied to imaging of the tibia, tendons and the skull of 10 healthy volunteers. Typical acquisition parameters included: FOV of 10 (for tibia and tendon) to 24 cm (for skull), TR of 300 ms, TE of 8 µs and 4.4/6.6 ms, bandwidth of ±62.5/125 kHz, readout of 512, 10 to 20 slices, slice thickness of 2 to 3 mm, 511 half projections with a total scan time of 5 minutes.

RESULTS AND DISCUSSION

Figure 1 shows axial UTE imaging of the tibia of a 54 year old healthy volunteer. Cortical bone is barely visible with regular UTE imaging. Conventional echo subtraction provides poor contrast between bone and muscle. UTE RDS provides high positive contrast for cortical bone, with a negative signal intensity for muscle and fat. The high bone contrast is not apparent on the absolute subtraction image. Figure 2 shows multi-slice sagittal tendon images with UTE dual echo, UTE subtraction and UTE RDS techniques. Again high positive contrast is achieved for tendon with high SNR and high spatial resolution. Figure 3 shows UTE RDS imaging of the skull, providing high contrast and whole coverage of skull structure. Future work will focus on optimizing the scaling factor to maximize the positive short T2 contrast.

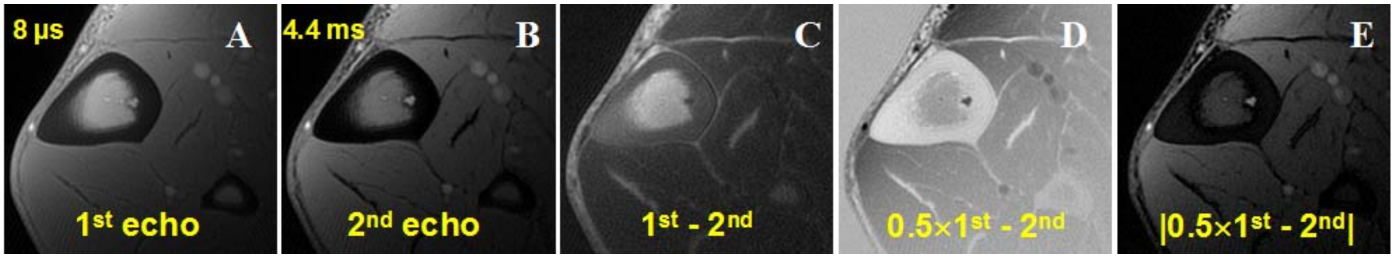

Fig 1 *Dual echo UTE imaging of the tibia of a volunteer with a TE of 8 µs (A) and 4.4 ms (B). Conventional echo subtraction produces limited contrast for cortical bone because of the high residual signal from bone marrow, muscle and skin (C). By scaling down the first echo by a factor of 0.5, signals from muscle and fat become negative while that from bone remains positive, creating high positive contrast for bone (D) which is not apparent on the absolute subtraction image (E).*

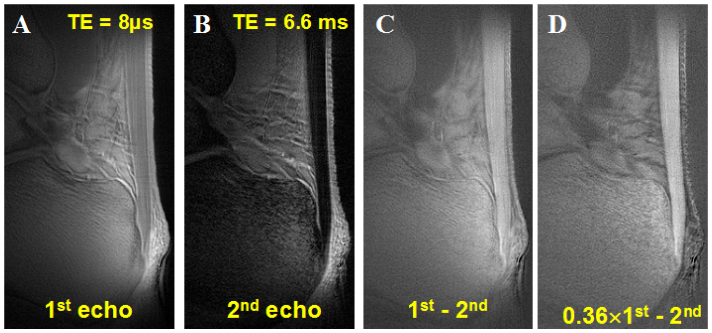

Fig 2 *Dual echo UTE imaging of the ankle of a volunteer in the sagittal plane with a TE of 8 µs (A) and 6.6 ms (B). Rescaled subtraction (D) provides improved contrast for the Achilles tendon over conventional echo subtraction (C).*

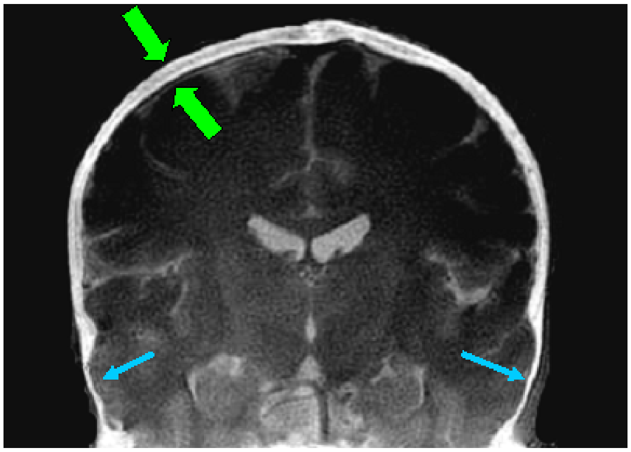

Fig 3 *Coronal UTE RDS imaging of the skull of a volunteer shows high positive contrast for cortical bone with two layers superior (thick arrows) and a single layer lateral (thin arrows).*

CONCLUSIONS

UTE RDS provides high positive contrast imaging of short T2 tissues, such as the cortical bone of the tibia, tendons and the skull with high spatial resolution, high SNR and contrast. It is very time efficient for volumetric coverage. This simple technique appears very promising for clinical evaluation of short T2 species.

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