MR cortical bone imaging using UTE for digitally-reconstructed radiographs and attenuation correction at 3.0T

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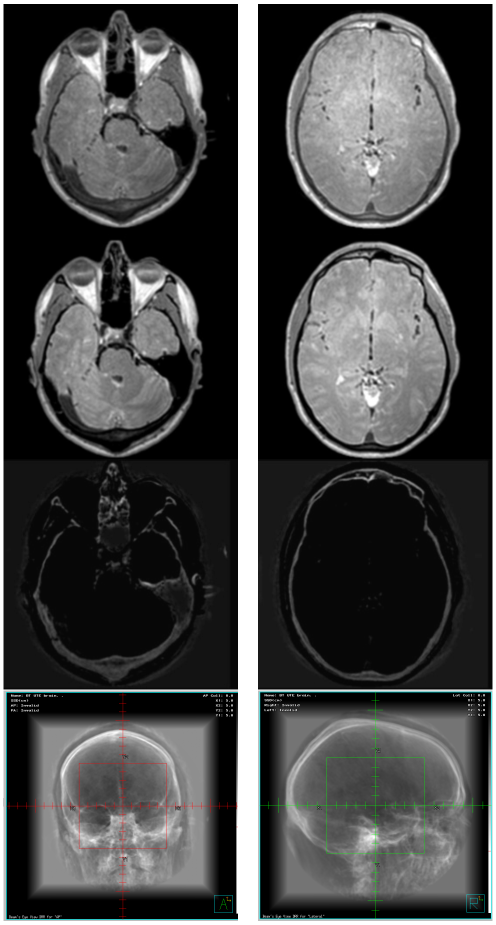

Figure 1. From the top: TE_1, TE_2, bone-enhanced images from two slices and DRRs.

Introduction

Conventional MR sequences with typical echo times (> 1ms) do not differentiate cortical bone from air, although this has been of little clinical consequence until recently. Two emerging MR applications, MR-based radiation therapy planning (RTP) and hybrid PET/MR systems, require complete segmentation of cortical bone for the construction of digitally reconstructed radiographs (DRRs) for 2D patient matching and generation of MR-based attenuation correction (AC) maps respectively. Accurate segmentation on MR is particularly difficult in anatomy where both bone and air are present, such as the facial sinuses. Sequences using an ultra-short echo time (UTE) have been used for imaging ultra-short T2 species such as tendons [1] or calcium [2] and have the potential to delineate signal from cortical bone versus air. Here, we investigate cortical bone imaging in the brain at 3.0T using a 3D UTE multi-echo acquisition and subtraction method for generation of DRRs.

Methods

As a preparation step, gradient channels were carefully calibrated to minimize off-resonance artifacts and the tune delay of the head coil was characterized for shortest switching time. Multi-echo data were then collected on four consented subjects (Philips Achieva 3.0T TX, Cleveland, OH) using an 8-channel head coil with the following parameters: 3D isotropic acquisition with radial readout, TE_1/TE_2 = 100µs/2.3ms, TR = 4.8ms, α = 15°, 1.4x1.4x1.4 mm^3 voxels, 200x200x200 mm^3 FOV, imaging time 4:06 min. In addition, a range of TEs were acquired in one subject using 2.9x2.9x2.9mm^3 voxels for an imaging time of 53 seconds per acquisition, TE_1 = 90-200µs in 10µs increments, TE_2 = 2.3ms, TR = 4.0ms, α = 10°, 210x210x210 mm^3 FOV. The TE_2 image was subtracted from the TE_1 image, to remove longer T2 species thereby enhancing bone visualization. The TE_2 image was acquired at the shortest possible in-phase echo time. The DRRs were generated on a Pinnacle workstation (Philips Healthcare, Fitchburg, WI).

Results

Figure 1 shows representative TE_1, TE_2, subtracted (bone-enhanced) images, and resulting DRRs. Figure 2 demonstrates the bone-enhanced images at several acquired TEs. Figure 3 depicts an overlay of the bone-enhanced image with the TE_2 image indicating negligible off-resonance artifacts from errors in hardware calibrations.

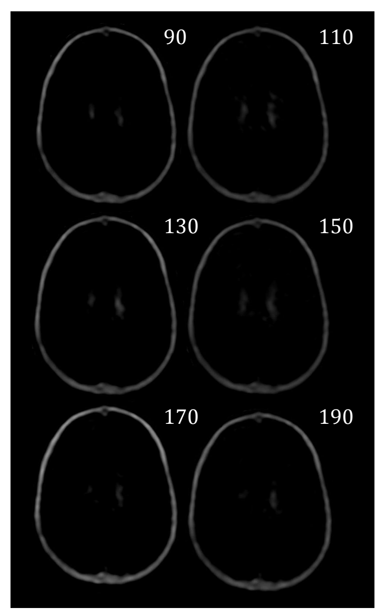

Figure 2. Bone-enhanced images from multiple UTEs.

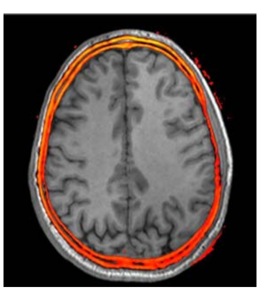

Figure 3. Color overlay of bone-enhanced image on TE_2 image.

Conclusions

A multi-echo UTE imaging method performs robustly for segmenting cortical bone in the brain. The DRRs generated from the bone-enhanced images appear sufficient for 2D patient matching. The range of TEs yielded excellent signal from cortical bone and the signal from bone, tissue and air were significantly different at all TEs (data not shown). When using the subtraction method, it is suggested that TE_2 be acquired at the (shortest) in-phase time to generate accurate results. Otherwise, the cancellation of the signal at the fat/tissue borders may be erroneously classified as air.

References 1. Du J, et. al. Magnetic Resonance Imaging 29 (2011) 470–482.
2. Sharma S, et. al. Investigative Radiology 45:3 (2010) 109-113.