

# Ultra-short TE (UTE) Imaging of Skull and a Quantitative Comparison of Skull Images Obtained from MRI and CT

L. Wang<sup>1</sup>, X. Zhong<sup>2</sup>, L. Zhang<sup>3</sup>, D. Tiwari<sup>1</sup>, and H. Mao<sup>1</sup>

<sup>1</sup>Department of Radiology and Emory Center for Systems Imaging, Emory University School of Medicine, Atlanta, GA, United States, <sup>2</sup>MR R&D Collaborations, Siemens healthcare, Atlanta, GA, United States, <sup>3</sup>Department of Radiology, Jinlin Hospital and Nanjing University College of Clinical Medicine, Nanjing, Jiangsu, China, People's Republic of

## Introduction

Magnetic resonance imaging (MRI) offers non-invasive imaging method to obtain high resolution anatomic pictures of tissue and organs. However, it has extremely low sensitivity to image the bone structures which have little water content and very short T2 relaxation time<sup>1,2</sup>. This is opposite to the problem of x-ray based computer tomography (CT), which has good capability of imaging of bone but poor capability in imaging of soft tissue. Although MRI has become a primary diagnostic imaging tool for clinical managements of various diseases and for research, it will be ideal if MRI can be used for imaging of both soft tissue and bone structure so that imaging of bone and tissue of patients can be done in the same scan session and doctors can obtain important diagnostic information on bone and its tissue interface. Furthermore, the ability of imaging of bone by MRI may also open up new MRI applications, such as using MRI for positron emission tomography (PET) attenuation correction that is critical in the latest development of the combined dual-modal MRI-PET technology. Recently an ultra-short time of repetition (UTE) MRI method has been reported for its potential application of bone imaging<sup>3-5</sup>. UTE imaging is capable of using extremely short echo time (TE) to allow for capture of signals from bone before substantial signal decay. The purposes of this study were to investigate imaging of skull using UTE MRI and to evaluate the quality of UTE skull images by comparing UTE bone images with those obtained from CT.

## Methods and Subjects

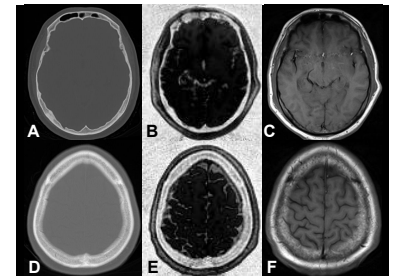
Eight subjects (5 men, 3 female; age range from 30 to 65 years) participated in this study under the approval of Institutional Review Board. CT images were collected followed by MR scans. All CT skull images were obtained using routine protocol with imaging parameters of 80 kV, 190 mA, 512 x 512 matrix, and 3-mm axial sections on a HiSpeed CT/iCT scanner (GE Healthcare). The MRI was performed on a 3 Tesla MR scanner (Siemens Medical Solutions) to obtain images covering the entire volume of the head. A multi-echo UTE sequence described previously<sup>6</sup> was used. This sequence consists of one 60 s long non-selective RF pulse followed by a 40 s transmit/receive switch time, and a 100% asymmetric data acquisition from the center to the surface of a sphere in the k-space using a three-dimensional (3D) radial sampling trajectory. The shortest TE used for this study was 0.07 ms; the second and longer TE was 2.76 ms. Other parameters included TR = 21.7 ms, flip angle = 15°, FOV = 22 x 22 cm<sup>2</sup>, image matrix = 192 x 192, bandwidth = 64000 Hz/pixel, total radial projections = 40 000, radial projections per excitation = 176, numbers of average = 2. The resultant skull MR images were obtained by subtracting images from two different TEs. The skull images of both CT and MRI were reviewed and evaluated by two raters blindly. To assess the geometrical match of skull bone structures from UTE and CT images, we compared skull thicknesses measured from MR and CT images in 7 regions of interest (ROIs) from each corresponding slice of the same subject. 5 slices were selected from each subject. In addition, UTE image of cortical bone were evaluated by comparing signal intensities of the outer layer, diploe, and inner layer of the skull measured from both CT and MR images. The ratios of bone intensity of MR images to bone intensity of CT images in different ROIs were calculated. The correlation of skull thickness between MR images and CT images were analyzed using Statistical Package (SPSS 15.0) and results are used to determine the quality of UTE images of the bone. Significance was defined as P < 0.05.

## Results and Discussion

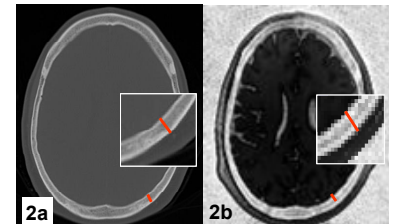
Cortical bone images were successfully obtained from all subjects using the UTE method. **Figure 1** shows two slices of brain images selected from different axial section of the head, showing cortical bone structure delineated by UTE MRI and CT. Skull structures can be clearly visualized in UTE images and matched well with that from CT. ROI analysis, as demonstrated in **Figure 2**, allowed us to evaluate and compare UTE bone images with CT more quantitatively. The comparison of the skull thickness measured from UTE and CT images are very close with a 10% at the directions of 3 to 10 clock in a selected slice. The skull thickness measured from UTE images showed good agreement with those obtained from CT images in different slices from the same subject as there is no statistical difference between the thickness measured from CT and UTE images (P = 0.87). There is also a good correlation between the thickness measurements obtained from CT and UTE images with R<sup>2</sup>=0.97 (**Figure 3**), suggesting that UTE images have minimal structural distortions. Further signal intensity based evaluation showed that there is no statistical difference in the signal intensity ratio (UTE:CT) in outer, inner layer and diploe of the skull (**Figure 4**). This study provided a quantitative evaluation of the skull images obtained using UTE MRI and a direct comparison to the skull images from CT. Although the resolution of the skull images measured by UTE MRI is lower than those typically obtained by the CT images, skull images obtained from UTE MRI offer sufficient image quality for providing diagnostic information. The comparison of bone thickness measured from skull images by UTE MRI and those of CT suggested that UTE MRI could provide a close-match image of the cortical bone. The relatively consistent ratios of the signal intensities of UTE and CT may help the development of attenuation correction algorithms which are of interest in the applications of the combined MRI-PET system.

## Conclusion

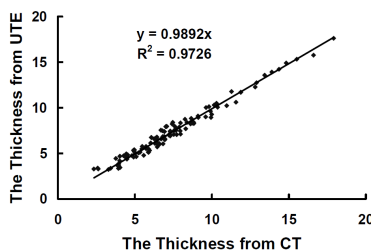
UTE MRI makes imaging of the short-T2 structures, such as cortical bone and skull, possible. Bone image obtained from UTE MRI enables MRI based PET attenuation correction when implemented in newly available combined MRI-PET system. With further increasing experience of improving and interpreting the bone images by UTE MRI, UTE MRI may provide a practical alternative to CT for bone imaging in some clinical situations.



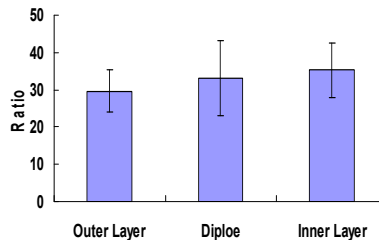
**Fig 1.** Examples from two slices of skull images of CT (A&D), UTE MRI (B&E) and T1WI (C&F).



**Fig 2.** Upper images showed examples of selecting region of interest (position 5) and measuring thickness of skull from CT (2a) and UTE images (2b).



**Fig 3.** Correlation of cortical bone thickness measured from UTE and CT images. Correlation coefficient was derived from 140 measurements of 70 ROIs and 20 slices.



**Fig 4.** Ratios of signal intensities from UTE and CT images of the skulls. The signal intensities were measured from slices of eight subjects

**References:** [1] Techawiboonwong A, et al, *Radiology*, 2008. [2] Tyler DJ, et al, *J Magn Reson Imaging*, 2007. [3] Robson MD, et al, *NMR Biomed*, 2006. [4] Reichert IL, et al, *Magn Reson Imaging*, 2005. [5] Robson MD, et al, *Magn Reson Med*, 2004. [6] Nielles-Vallespin et al. 17th ISMRM 2009; 2654.

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