High-Resolution 3D UTE Imaging Of Cortical Bone

A. S. Issever[1,2], P. Larson[1], S. Majumdar[1], D. Vigneron[1], R. Krug[1], W. Chunsheng[1], and T. Link[1]
[1]UCSF, San Francisco, CA, United States, [2]Charité, Berlin, Germany

INTRODUCTION: Aside from bone mineral density (BMD), the most important parameters responsible for bone quality are those measuring trabecular and cortical bone micro- and macrostructure [1]. Among the microstructural measures of cortical bone, porosity has been identified as a major contributor to bone strength [2, 3]. Particularly at central sites such as the hip efforts have focused on investigating the relationship between cortical bone porosity and increased fracture risk [4-7]. However, so far it has been difficult to quantify cortical bone porosity in vivo: standard CT and MR techniques do not visualize cortical porosity though cortical BMD obtained from standard CT has been used and suggested as a surrogate marker [3]. Recently ultra-short TE (UTE) MR imaging has been introduced to depict signal from - and thus image - cortical bone [8, 9]. Briefly: UTE imaging allows the detection of signal components with T2 relaxation times on the order of only a few hundred microseconds, which are found in highly ordered tissues such as menisci, ligaments and cortical bone (T2 = 0.42-0.50 ms [9]). Techawiboonwong et al. recently published two studies in which UTE imaging was used to quantify cortical bone water content, thus providing an indirect measure of cortical porosity [10, 11]. Imaging was done at a nominal voxel size of 0.2 x 0.2 x 5 mm^3 (ex vivo) and 0.3 x 0.3 x 8 mm^3 (in vivo). In the current study we applied a high-resolution 3D UTE sequence with an isotropic voxel size of 0.4 x 0.4 x 0.4 mm^3.

MATERIALS AND METHODS: Imaging was performed on a human cadaver proximal femur shaft (76 years; male). Prior to imaging bone marrow was largely removed out of the medullary cavity. For reference purposes two 27 mmol/L $MnCl_2$ doped phantoms consisting of 10% and 20% H_2O/D_2O concentrations were used. 3D UTE imaging [12] was done on a 3-T Signa MRI system (General Electric, Milwaukee, WI, USA) with maximum gradient amplitude and slew rates of 40 mT/m and 150 T/m/s, and the following sequence specifics (TR = 5ms; TE = 64 µs; 20° FA; non-selective hard-pulse; 1024 µs readout duration; 0.4 x 0.4 x 0.4 mm^3; 6 x 6 x 6 cm FOV; 4 NEX; TR saddle coil; gridding reconstruction).

RESULTS: Our results are depicted in Figure 1.

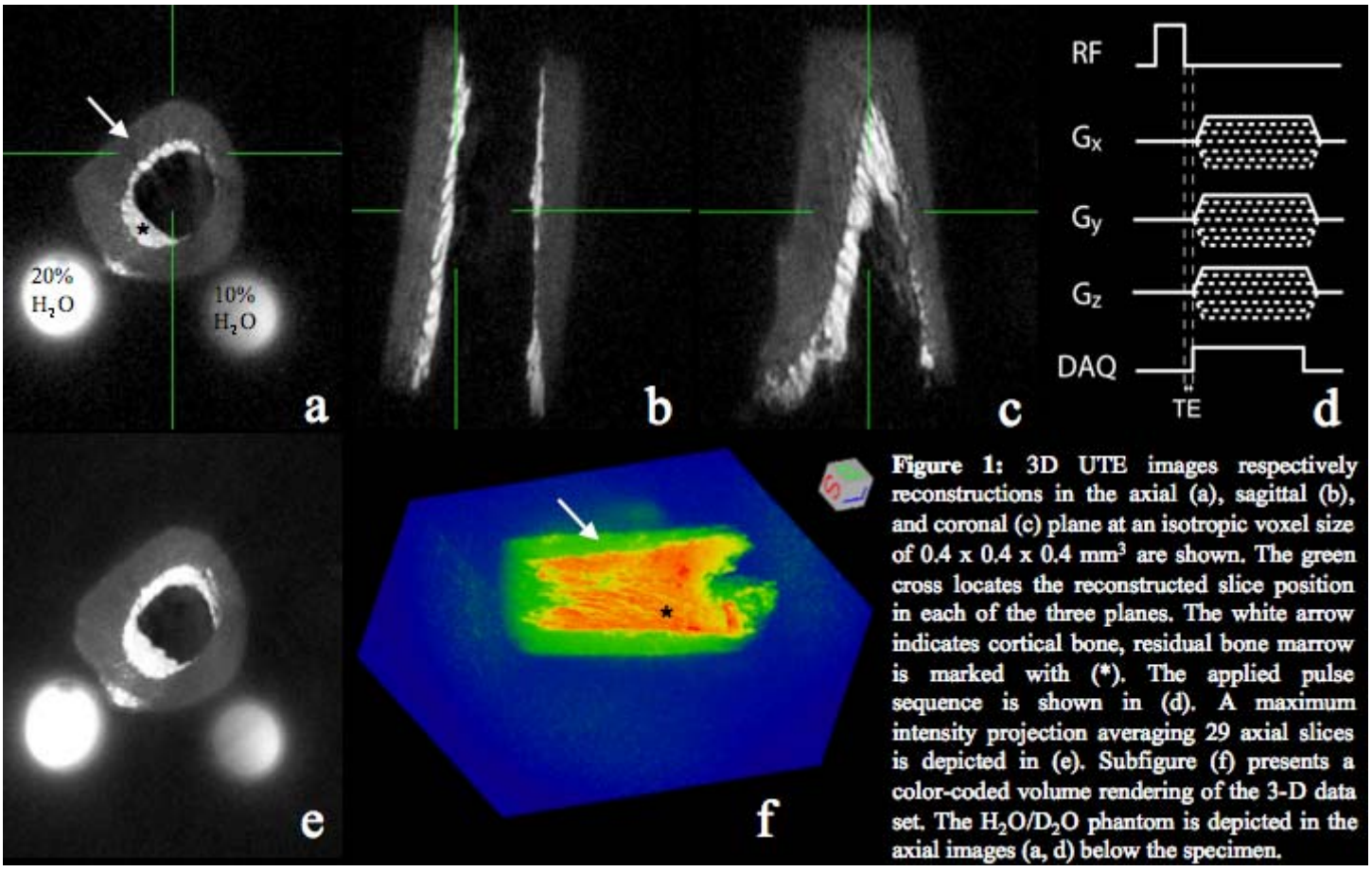

Figure 1: 3D UTE images respectively reconstructions in the axial (a), sagittal (b), and coronal (c) plane at an isotropic voxel size of 0.4 x 0.4 x 0.4 mm^3 are shown. The green cross locates the reconstructed slice position in each of the three planes. The white arrow indicates cortical bone, residual bone marrow is marked with (*). The applied pulse sequence is shown in (d). A maximum intensity projection averaging 29 axial slices is depicted in (e). Subfigure (f) presents a color-coded volume rendering of the 3-D data set. The H_2O/D_2O phantom is depicted in the axial images (a, d) below the specimen.

DISCUSSION: UTE MR imaging promises to be a powerful alternative to quantify bone quality in cortical bone aside from its density. It may thus be considered a potential new tool in the assessment of fracture risk or in the monitoring of osteoporosis therapy. In this study we introduce a high-resolution 3D UTE MR sequence that is capable of depicting cortical bone at an isotropic voxel size below 500 µm allowing instant image reformation.

REFERENCES:

1. Seeman E, et al., N Engl J Med 2006
2. Augat P et al., J Bone Miner Res 1996
3. Bousson V et al., Radiology 2000
4. Bell KL et al., Bone 1999
5. Bell KL et al., Anat Rec 2001
6. Bousson V et al., J Bone Miner Res 2004
7. Jordan GR et al., Bone 2000
8. Reichert IL et al., Magn Reson Imaging 2005
9. Robson MD et al., J Comput Assist Tomogr 2003
10. Techawiboonwong A et al., Radiology 2008
11. Techawiboonwong A et al., NMR Biomed 2008
12. Rahmer J et al., Magn Reson Med 2006

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