MR-based Attenuation Mapping of the Pelvis Using 3D UTE DIXON at 3T

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Introduction

MR-based radiation therapy planning (RTP) and hybrid PET/MR systems require a complete segmentation of bone, soft tissue, and air for attenuation correction. Conventional MRI sequences cannot reliably differentiate between air and bone due to the fast T2 decay. Promising results for cortical bone were obtained with 3D ultrashort echo time imaging (UTE) in the knee [1] and head [2,3]. However, UTE bone imaging in the pelvis is more demanding due to the significantly larger FOV. A UTE Dixon sequence and reconstruction workflow is presented, which provides good *in vivo* image quality and reliable bone segmentation over a 400mm FOV.

Methods

Experiments were performed in five healthy adults on a clinical wide-bore MRI system (Ingenia 3.0T, Philips Healthcare) using 12 posterior and 16 anterior coil elements. A 3D radial triple-echo sequence (TE1=0.09ms, TE2=1.0ms, TE3=2.1ms) was used. Imaging parameters were TR=4.6ms, α=10°, FOV=400x400x400mm³, measured resolution 2x2x2mm³, scan time 224s. B1 shimming and receive coil sensitivity mapping were used for uniform representation. A schematic diagram of the reconstruction algorithm is sketched in Fig. 1. A DIXON reconstruction was employed to extract fat and water fractions from (nearly) in-phase and out-phase images (TE2 and TE3), whereas a UTE image for visualization of short T2 components was obtained with the FID (TE1). Subtraction of TE3 and TE1 yields bone-enhanced images. A global and linear phase correction (PC) was used for echo top centering to improve SNR and image quality for subtraction imaging, whereas PC was bypassed for the DIXON reconstruction to preserve the relative phase coherence. Water and fat images were used to exclude undesired signal from the bone enhanced image, yielding separate data sets of bone, water and fat exclusively. Attenuation maps for 511keV were obtained by assigning the known attenuation values of soft tissue (0.10cm^{-1}), adipose tissue (0.09cm^{-1}), air (0.003cm^{-1}), and bone (0.17cm^{-1}) to the classified voxels. For further illustration, a digitally reconstructed radiograph (DRR) was calculated from the volumetric attenuation maps.

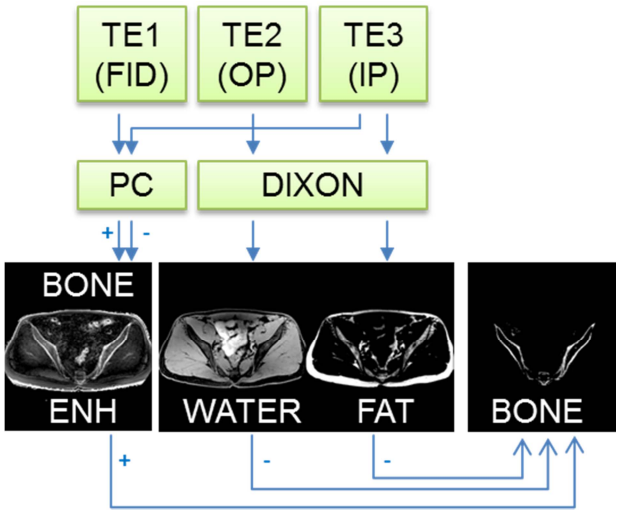

Fig. 1 Schematic overview of reconstruction algorithm. A subtraction of phase-corrected FID and in-phase data yields a bone enhanced image. The phase correction is bypassed for the DIXON reconstruction, which yields fat and water images. These are used to mask undesired signal from the bone image.

Results

A good segmentation of bone, soft tissue, and adipose tissue was achieved across the entire FOV in all volunteers. Selected attenuation maps and DRRs are shown in Fig. 2 [a-d]. Bowel content was mis-classified as bone due to its similar MR properties in some slices (solid arrow).

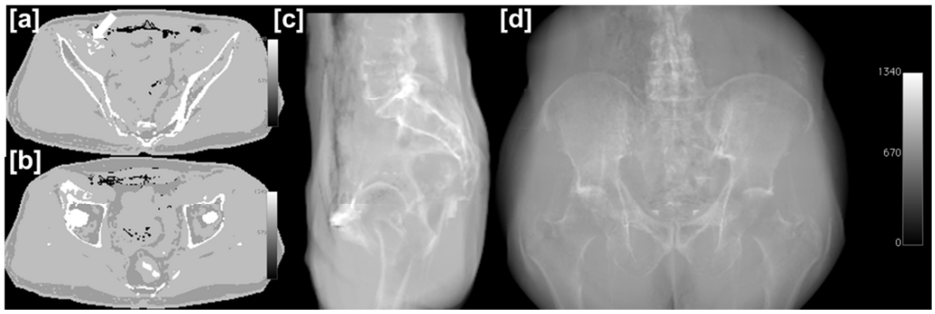

Fig. 2 Two slices from the attenuation map obtained by assigning corresponding attenuation values to air, water, fat and bone voxels [a,b]. This allows reconstructing a digital radiograph (DRR) in sagittal and coronal orientation [c,d].

Discussion and conclusion

Good *in vivo* results of MR-based attenuation maps of the pelvic bone were obtained over a large FOV using the present triple-echo UTE DIXON sequence and reconstruction workflow. This is an integral component of emerging applications such as MR-based therapy planning, and hybrid PET/MR systems. The acquisition of the additional FID image comes without a scan time penalty when compared with standard DIXON, but provides important data for tissue/air segmentation. Furthermore, due to its short echo time, it may provide better tissue delineation near metal as a future refinement. A pre-segmentation of bowel content may be required to avoid misclassification.

References: [1] Rahmer J et al, 18th ISMRM #3224, 2010 [2] Berker Y et al, J Nucl Med. 2012 53:796-804 [3] Kotys-Traughber MS et al, 20th ISMRM, #286, 2012