Whole-Body UTE-mDixon: a potential one-scan solution for PET/MR attenuation correction and localization

Lingzhi Hu[1], Christian Stehning[2], Holger Eggers[2], Zhiqiang Hu[1], and Lingxiong Shao[3]
[1]Philips Healthcare, Cleveland, OH, United States, [2]Philips Research, Hamburg, Germany, [3]Philips Healthcare, San Jose, United States

Target Audience: Clinicians and researchers interested in PET/MR and MR-guided radiation therapy.

Introduction: MR-based Attenuation Correction (MRAC) is crucial for PET quantitation and image quality in a hybrid PET/MR system. An ideal MR sequence for attenuation correction should at least satisfy three criteria: (1) whole-body scan capabilities; (2) good anatomical localization; (3) robust tissue classification. UTE-mDixon sequences have demonstrated great potential for enhancing contrast of cortical bone and for water/fat separation within a single acquisition. Herein we report our initial experience of utilizing a UTE-mDixon sequence for whole-body PET/MR attenuation correction.

Method: Eight healthy volunteers were recruited for whole-body UTE-mDixon MR scans on a Philips Ingenuity PET/MR system. Before each individual scan, gradient channels were carefully calibrated to minimize trajectory inaccuracies and FID echo times were minimized by tuning the coil transmit/receive switching delay. A radial encoding 3-echo UTE sequence (Fig. 1) was performed at five different bed positions for body coverage from eye to thigh. Respiratory motion was carefully controlled by gating the sequence at the end expiration phase. TEs were selected to be 0.08, 1.1 and 2.2 ms, and images from the last two echoes were used for a modified Dixon method[1] for water/fat separation. Other imaging parameters were: TR = 6ms, α = 20°, 1.56x1.56x1.56 mm^3 voxels, 500x500x500 mm^3 FOV, and ~5mins imaging time per bed position, depending on the breathing pattern. Signal transmission and reception was performed with the integrated quadrature body coil. Bone-enhanced images were generated by normalized subtraction of the in-phase (third echo) images from the corresponding FID (first "echo") images. The product MRAC segmentation algorithm was used for automatic model-based lung (and body contour) detection in the FID images.

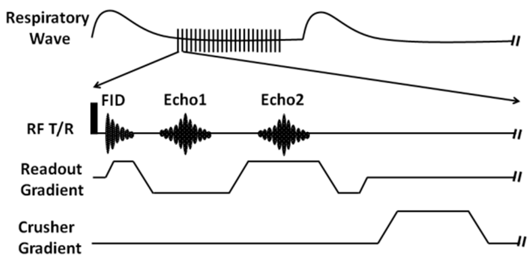

Figure 1. UTE-mDixon pulse sequence with respiratory gating for whole-body MRAC.

Result: FID, in-phase, water and fat images (Fig. 2) acquired with the UTE-mDixon sequence exhibited good SNR and soft tissue contrast. Consistent water/fat separation was achieved throughout all body parts. The bone enhancement images provide positive contrast of cortical bone throughout all body parts. It is notable that, as reported in the past[2], lung tissue which is otherwise difficult to visualize also yields prominent signal in the subtracted images because of its short T2*. No volunteers complained about any uncomfortability during and after the whole-body UTE-mDixon scan. Automatic body and lung segmentation in the FID images was successful in 7/8 cases (Fig. 3) while moderate under-segmentation was present in 1/8 case due to artifacts in the FID images.

Discussion: Because MR FOV is smaller than PET, missing tissue in MR images need to be refilled by "truncation compensation[3]" for PET/MR attenuation correction. In addition, because another emerging hybrid system: MR-based radiation therapy planning (RTP) also requires complete segmentation of cortical bone for the construction of digitally reconstructed radiographs (DRRs) for 2D patient matching. The same technique can be translated into RTP and improve the accuracy of radiation dose calculation.

Conclusion: We utilized a UTE-mDixon pulse sequence for whole-body attenuation correction in PET/MR. Cortical bone could be visualized with prominent positive contrast in bone-enhanced images generated from FID images with an ultra-short echo time of 0.08 ms and an in-phase image. Satisfying water/fat separation was achieved with mDixon and radial multi-echo sampling. In conclusion, the UTE-mDixon pulse sequence is a promising one-scan solution for attenuation correction and anatomical localization in PET/MR and for MR-based RTP.

Reference: [1]: Eggers H, Brendel B, Duijndam A, Herigault G., Magn Reson Med. 2011 Jan;65(1):96-107.
[2]: Togao O, Tsuji R, Ohno Y, Dimitrov I, Takahashi M., Magn Reson Med. 2010 Nov;64(5):1491-8.
[3]: Hu Z, et al, Philips Ingenuity TF PET/MR attenuation correction white paper

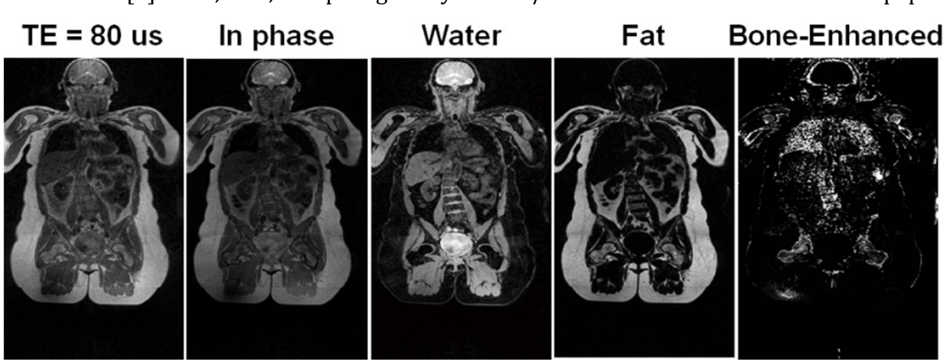

Figure 2. Representative images from whole-body UTE-mDixon scan.

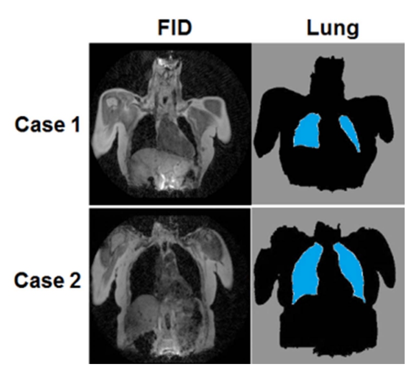

Figure 3. Body contour and lung segmentation in FID images using PET/MR product algorithm.