UTILE – A fast combined UTE-DIXON four class attenuation correction technique for PET/MR

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Introduction: Accurate high energy gamma photon attenuation correction (AC) is essential for quantitative positron emission tomography (PET) in a combined PET/MR device. In difference to CT, there is no simple relation between the MR image intensity and the linear attenuation coefficients (LACs). For instance cortical bone and air filled cavities show in conventional MR sequences (nearly) no signal intensity whereas their LACs are substantially different [1]. Several groups propose to use ultrashort echotime (UTE) sequence [2] to separate cortical bone and air, while on the other hand other groups propose the Dixon technique [3] to distinguish between soft tissue and adipose tissue. To furthermore increase the accuracy of the AC, reliable classifications of additional tissue classes would be needed, while the MR-acquisition time should be primarily used for the diagnostic scans. Thus sequential application of these two the UTE and Dixon for AC would be a sub-optimal solution.

Methods & Materials:
MR sequence: We propose a new UTE triple-echo (UTILE) MR-sequence combining the UTE and DIXON acquisition in a single shot. The fast induced decay (FID) is sample at short echo times (TE1) followed by two gradient echoes (TE2,TE3) adjusted to where water and fat are almost opposed- and in-phase, respectively. (TE1/TE2/TE3/TR=0.09/1.09/2.09/4.1ms for 3T; FOV: 280^3mm^3; matrix size (acq./recon.): 160^3/240^3, voxel size (acq./recon.): 1.75^3/1.17^3mm^3; water-fat-shift: 0.226 pixel; receiver coil: NeuroVascular 16 element; scan time < 4min; conducted on Philips 3T Achieva). To achieve an ultrashort TE, a hard, non-selective RF block-pulse with flip angle of 10° (RF pulse width ~51μs) is applied for volumetric excitation followed by a three dimensional radially center-out sampling scheme.
Post-processing: Cortical bone is segmented from the calculated relative difference between the magnitude information of echo one (M_1) and echo three (M_3) by an empirically determined global threshold after masking out air areas. Air areas where derived from the phase information of the first "echo" by thresholding. Soft tissue and adipose tissue decomposition is achieved by applying a three-point Dixon signal modelling using the magnitude and the unwrapped phase [4] information of all three echoes. The four segmented classes where assigning with appropriate LACs (extracted from [1]) of their respective tissue class to generate a truly MR-based attenuation map (μ-map).

Results: Fig. 1 shows exemplarily one transversal slice of the proposed MR-based μ-map (a) and the gold standard computed tomography (CT)-based μ-map (b) of one volunteer dataset from which an old (approx. 1.5 years) CT head dataset was available. By bilinear transformation [5] the CT dataset was transformed into the LACs space at 511keV prior to manual alignment to the MR-based μ-map. From both datasets 60 slices where radon transformed to end up in the sinogram domain and plotted in a joint histogram (c.f. Fig. 2) including the trend line and the coefficient of determination (R2).

Conclusion: We have shown the feasibility of the single shot UTILE MR-sequence allowing for generation of a truly MR-based four-compartment μ-map with high correlation to the gold standard CTAC method without making any assumptions with regard to the patient's anatomy. This technique is also applicable for radio-therapy planning.
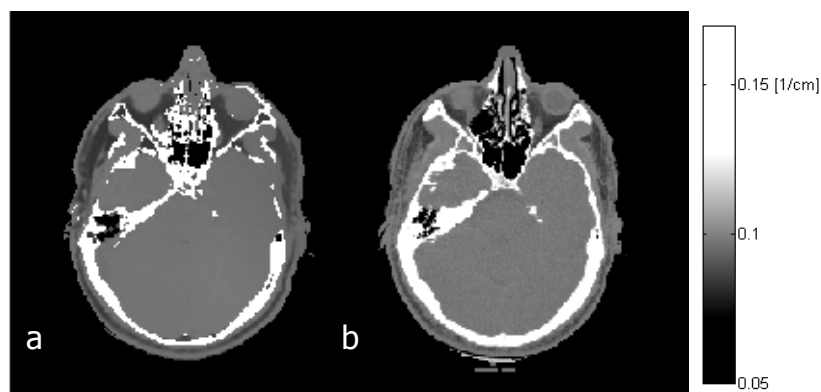

Figure 1: Transversal μ-map slice of a healthy volunteer head derived from a) the new proposed UTILE MR-sequence and b) the gold standard CT-derived μ-map.
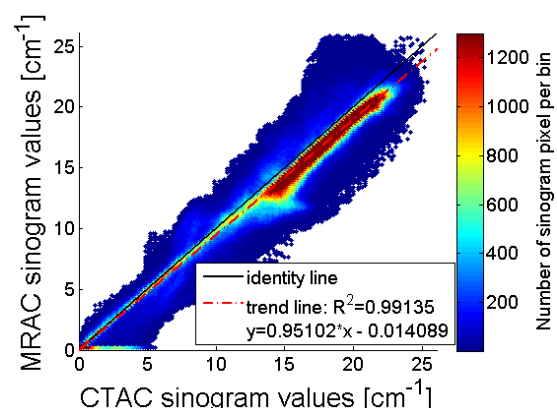

Figure 2: Joint histogram of 60 μ-map slices of the newly proposed MRAC technique and the gold standard CTAC technique transformed into sinogram space.

References:
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