

MR-based attenuation correction utilizing multi-echo flyback UTE IDEAL.

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Target Audience: Physicists, engineers and clinicians interested in PET/MR imaging

Purpose: Quantitative PET imaging in PET/MR systems requires reliable methods for MR-based attenuation correction. While robust MR methods have been described to reliably distinguish fat and water within soft tissue, current MR methods provide limited sensitivity to lung tissue and bone, both of which exhibit substantially different photon absorption. Ultra short echo time imaging holds potential to overcoming the limitations of more conventional imaging techniques [1], but is unfortunately challenging in many application due to low signal to noise (SNR) and obscuring signal from fat and water. This is especially true in body applications in which motion must also be managed. In this work, we present work towards the development of motion-robust MR-based attenuation correction (MRAC) techniques to segment MR images into water and fat components of soft tissue, bone, and lung.

Methods: To enable imaging of bone and lung, an ultra-short TE (UTE) radial acquisition was utilized in combination with an IDEAL-like reconstruction for quantitative water-fat separation. As shown in Figure 1, a UTE sequence was extended collect multiple echoes acquisitions utilizing a flyback trajectory [2]. After reconstruction of each echo time, images were separated into water, fat, and short-T2* species utilizing an adaptation of the quantitative IDEAL signal model:

$$S(TE) = \begin{cases} \left(\rho_{Water} + \rho_{Fat} e^{i2\pi\Delta f \cdot TE} \right) e^{-TE_0/T2^*_{Long}} + \rho_{Short} e^{i\psi \cdot TE} & TE_0 \\ \left(\rho_{Water} + \rho_{Fat} e^{i2\pi\Delta f \cdot TE} \right) e^{-TE/T2^*_{Long}} \cdot e^{i\psi \cdot TE_i} & otherwise \end{cases}$$

where ρ_{Water} , ρ_{Fat} , ρ_{Short} are the signal components from water, fat, and short-T2* species, Δf is the chemical shift of fat, $T2^*_{Long}$ is the T2* of soft tissue components (>1ms), and ψ is the off-resonance due to B_0 inhomogeneity. The bottom equation is the traditional fat/water signal model and the top equation includes an additional signal from short-T2* species (<1ms). Since the evolution of the short T2* signal is not modeled, only a single image with TE of approximately zero is needed. Thus, images can be collected in a single pass using multi-echo readouts. Attenuation correction maps may be generated by combining definite ratios of the each component from the above signal model. Seeded region growing [3] algorithm, with automatic seed selection, is then used to identify the boundary of the body and the lungs. In combination with these boundaries, global thresholding of the normalized component ratio images enables segmentation into water and fat components of soft tissue, bone, and lung. Attenuation correction images (μ -map) is then generated from a linear combination of the segmented components with known linear attenuation coefficient values.

Results and Discussion: To demonstrate the motion robustness of our technique, a scan obtained in the chest of a volunteer is shown in Figure 2. The parameters of the acquisition were: 3T GE MR750 scanner, 8 echoes, $TE_0 = 100\mu s$, $\Delta TE = 0.7ms$, $TR = 10ms$, $\alpha = 10^\circ$, 30,000 projections, resolution = 2.5 mm isotropic. Images were obtained under free breathing using respiratory triggering (~50% efficiency) with a scan time of approximately 10 minutes. Cardiac gating was not used; however, cardiac motion does not perturb tissue segmentation. We expect similar performance in other regions of the body, where scan time is significantly less when physiological triggering is not needed.

Conclusion: We have demonstrated differentiation of soft tissue, bone, and lung tissue in a difficult MR environment such as the chest. The utilization of a single acquisition that provides meaningful contrast in short-T2* tissues such as the lungs and bone as well as quantitative separation of soft tissues may provide robust and reliable tissue segmentation for MRAC on MR/PET multimodality systems.

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References: [1] Keereman et al., *J Nuc Med*, 2010, 51(5). [2] Johnson et al. *ISMRM 2013*, #0646. [3] Adams and Bischof. *IEEE TPAMI*, 1994, 16(6).

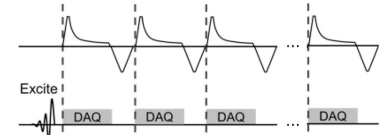


Figure 1. Multi-echo fly-back UTE pulse sequence schematic.

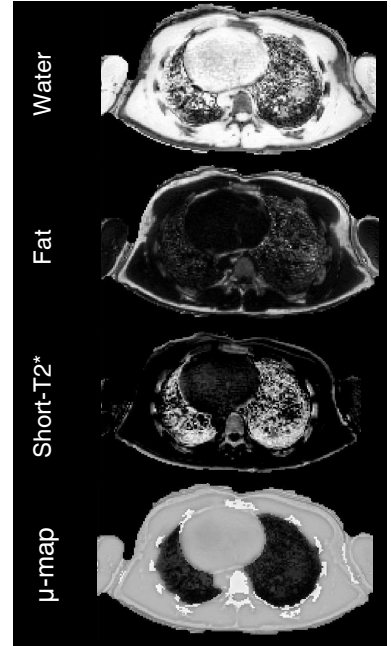


Figure 2. Example MRAC acquisition in a volunteer.