

Performance of Chemical Shift-based Water-fat Separation with Self-calibrated Fat Spectrum is Sensitive to Echo Times

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Introduction Chemical shift-based water-fat separation method provides an effective way either to measure fat fraction in tissue, or to suppress fat signal which might obscure underlying pathology. To completely separate water and fat, the spectral complexity of fat should be included in the signal model. IDEAL (Iterative decomposition of water and fat with echo asymmetry and least-squares estimation) algorithm with multi-peak fat spectral modeling has been introduced [1]. Recent studies have discussed the accuracy and noise performance of the multi-peak IDEAL algorithm assuming that the frequencies and relative amplitudes of fat peaks are constant among all subjects [2,3]. However, the fat spectra differ with the different depot of fat, thus a self-calibration method which estimates the fat spectrum directly from the data performs better [1,4]. In this work, we analyze the performance of multi-peak IDEAL algorithm with self-calibrated fat spectrum by means of theoretical calculation, simulation, phantom and in vivo experiments.

Methods The self-calibration algorithm consists of two steps. In the first step, a 6-point T2*-IDEAL method separates three main fat peaks and water as four different species, and then averages relative amplitude of each fat peak over fat-rich pixels to obtain the fat spectrum model; in the second step, fat and water are separated using a modified IDEAL algorithm incorporating the estimated multi-peak fat spectrum from the 1st step. The accuracy and noise performance were analyzed for both steps separately as well as the final result.

Simulation 6-echo source images were simulated for different ΔTEs (echo time increments) and different fat fractions. For each combination, 100 simulated pixels were generated with Gaussian noise added to the signals.

Phantom construction A water-fat phantom including 7 tubes with fat-fractions of 10%, 20%, 30%, 40%, 53%, 60%, 100% was built as described in [5].

Data acquisition Phantom and in vivo scans were performed on a Philips Achieva 3.0T scanner using a multi-acquisition FFE sequence. The phantom scans were repeated 33 times for each ΔTE .

Results and Discussion For step 1, the NSA and mean values of fat peak amplitudes are shown in Figure 1. NSA values are close to zero at ΔTE below 0.5 ms or close to 1.9 ms, which indicates that the amplitudes cannot be stably estimated in these regions. It's worth noting that since the relative amplitudes are averaged over many pixels, small NSA (but not close to zero) is tolerable. This is consistent with the mean values of the estimated relative amplitudes, which are stable and close to the results in previous studies [1,6] with ΔTE between 0.7ms and 1.6ms. For step 2, as shown in Figure 2, NSA for fat magnitude is close to the maximum possible value and insensitive to ΔTE difference, indicating that step2 is stable in a wide range of ΔTE values. The final results on the phantom show that they are mainly affected by the effectiveness of the calibration step, which is shown in Figure 3. In vivo results are demonstrated in figure 4, and the influence of different ΔTEs is in good agreement with results of theoretical prediction, simulation and on phantom.

Conclusion The performance of self-calibration multi-peak IDEAL algorithm is heavily dependent on the chosen ΔTE , which affects the accuracy of fat spectrum calibration. ΔTE values between 0.7ms and 1.6ms can provide reliable water-fat separation.

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Reference

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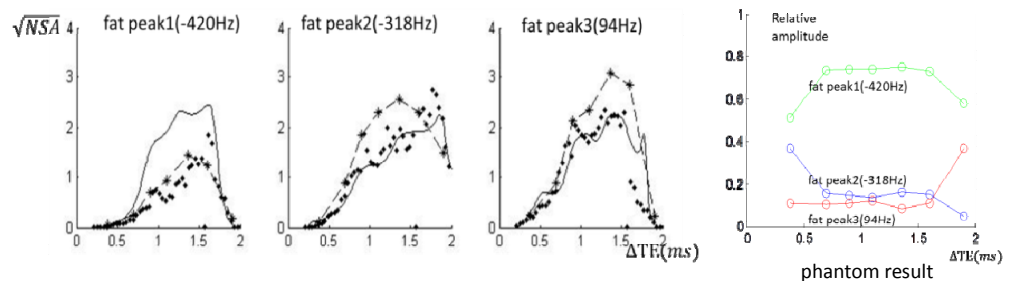


Fig 1. NSA calculated from simulation data (dots) and phantom data (stars) follows similar patterns. The difference between NSA results and the Cramer-Rao bound (CRB) predictions (solid line) is due to model mismatch.

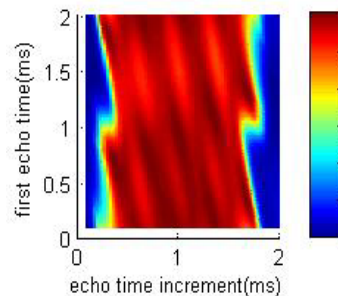


Fig 2. The NSA of fat magnitude estimated by CRB, assuming the calibration is correct.

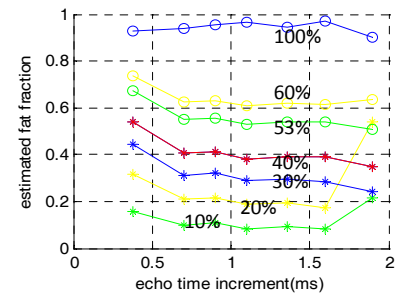


Fig 3. Final result on phantom is mainly influenced by the effectiveness of the calibration step.

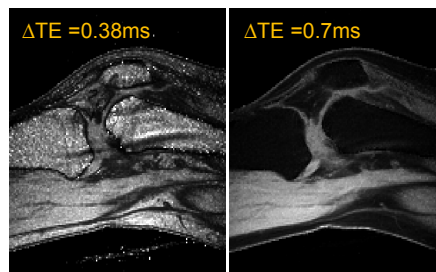


Fig 4. Calculated fat images in the knee of a healthy volunteer. The acquisition and processing procedures except for ΔTE are the same for the two images: $TE_1=1.89ms$, $TR=110ms$, voxel size= $1*1*8mm$.