Influence of Relaxation on Fat Suppression by Dixon Methods in Musculoskeletal MRI

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Introduction

Dixon methods rely on signal acquired at different echo times for the separation of water and fat. Consequently, any discrepancy between the modeled and the actual signal evolution leads to errors. While the signal models employed for the separation originally assumed a single-peak spectrum for both species and considered main field inhomogeneity only, a more complex fat spectrum and transverse relaxation have been included lately [1,2]. In this work, the relevance of these additions is evaluated in musculoskeletal imaging, where the simpler signal models are particularly challenged by the occurring short relaxation rates.

Methods

Data were simulated using a three-peak fat spectrum (75% at -3.3 ppm, 15% at -2.5 ppm, 10% at 0.7 ppm relative to water) and a common rate of exponential decay. They were reconstructed by fitting the parameters of simpler signal models to them [3]. The attained degree of fat suppression was assessed for different relaxation rates R_2^*, echo spacing ΔTE, and number of echoes N_E by quantifying the relative amount of leakage of fat into water signal.

Measurements on joints of volunteers were carried out on a Philips 1.0 T Panorama scanner with a 3D spoiled gradient-echo sequence with different ΔTE and N_E.

Results

Figs. 1 and 2 summarize results of simulations for a field strength of 1.0 T, in which the signal model for the separation included a single-peak fat spectrum and optionally transverse relaxation. Without relaxation, leakage grows with R_2^*, but depends strongly on ΔTE and N_E. Using three echoes, for instance, minimal leakage is obtained for a broad range of R_2^* values with $\Delta TE \approx 3.5$ ms, which corresponds to approximately 180° dephasing between water and fat signal. With relaxation, leakage remains almost constant with increasing R_2^* and essentially drops with longer ΔTE.

Fig. 3 presents examples of ankle images acquired with ΔTE = 2.3 ms, which is, according to Fig. 2, a good choice for $N_E = 4$, but not for $N_E = 3$. The residual signal in the calcaneous is reduced by about 50% using $N_E = 4$ instead of $N_E = 3$. Alternatively, the inclusion of relaxation in the signal model for the separation leads to a decrease of about 30% and also limits leakage to less than 10%.

In general, it was found that the experimental and theoretical results agreed qualitatively, but that the predicted degree of fat suppression was usually not fully reached in practice.

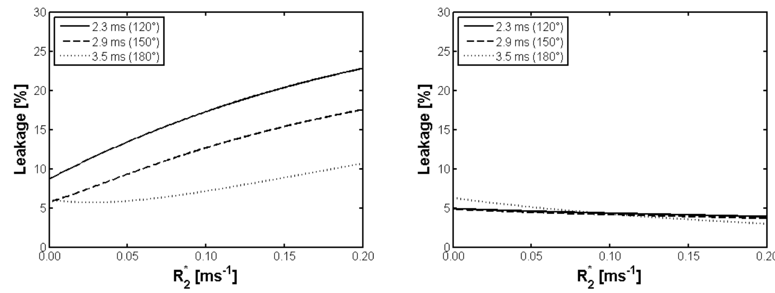

Fig. 1. Relative amount of leakage of fat into water signal as function of the relaxation rate R_2^* using three echoes with different spacing, excluding (left) and including (right) relaxation in the signal model for the separation.

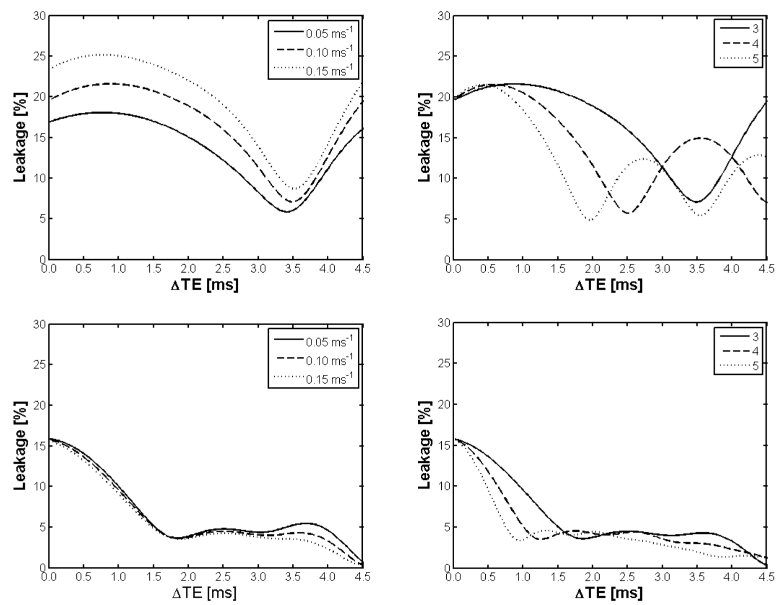

Fig. 2. Relative amount of leakage of fat into water signal as function of the echo spacing ΔTE using three echoes and different relaxation rates (left) and three to five echoes and a relaxation rate of 0.1 ms^{-1} (right), excluding (top) and including (bottom) relaxation in the signal model for the separation.

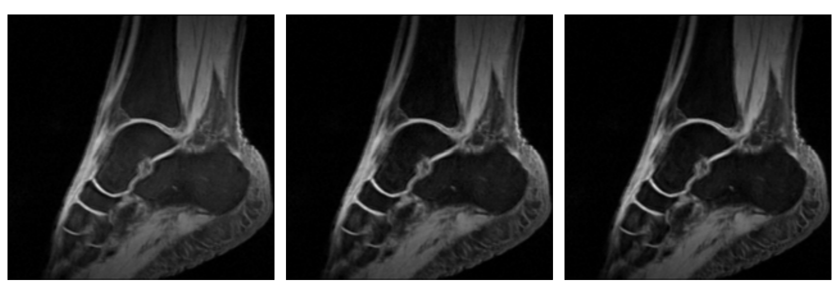

Fig. 3. Selected slice from an ankle data set. Shown are water images obtained from three (left, middle) and four (right) echoes, excluding (left, right) and including (middle) relaxation in the signal model for the separation.

Conclusions

Prospective chemical shift-based fat suppression methods typically eliminate fat signal from spectral peaks around 3.5 ppm only and thus produce between 5% and 10% leakage. In many applications of musculoskeletal imaging, this is considered acceptable, or, in view of the widespread use of weak fat suppression, even too low. The presented results suggest that a similar degree of fat suppression may be attained by Dixon methods without detailed knowledge of the fat spectrum by either choosing ΔTE and N_E appropriately or by including relaxation in the signal model for the separation. In both cases, a compromise between the optimization of leakage, signal-to-noise ratio, and scan time has to be made.

References

1. Yu H, et al. J Magn Reson Imaging 2007; 26:1153-1161. 2. Yu H, et al. Proc ISMRM 2008; 652. 3. Reeder SB, et al. Magn Reson Med 2004; 51:35-45.