T1 and T2 Relaxation in Fat Quantification using FSE Sequences

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Introduction

Fast spin echo (FSE) imaging with fat saturation has been recently proposed as a promising technique for accurate fat quantification (1). Fat quantification is achieved by determining relative signal loss from T2-weighted FSE images with fat saturation to those without fat saturation. An advantage of this technique is that it eliminates the potential for T2* decay effects that may contribute to the inaccuracy of more popular Dixon techniques utilizing gradient recalled echo imaging (2). This error can be large in patients with steatosis and chronic liver disease, where T2* decay may be significant (3). However, there are several sources of potential error that may contribute to inaccuracy of fat quantification with the FSE technique. These include consistency and reproducibility of fat saturation, k-space sampling technique variability for differing TE values and the contribution of T1 and T2 decay. We present calculations to determine the potential impact of T1 and T2 relaxation upon the accuracy of fat quantification utilizing the FSE with fat saturation imaging technique.

Methods

The single shot FSE sequence may be expected to have a dependence on TR and TE give by the spin echo signal equation. For water (W) and fat (F) these are given below.

$$W = \rho_w \,.\, (1 - \exp(-TR/T1_w)) \,.\, \exp(-TE/T2_w) \quad \textit{and} \quad F = \rho_f \,.\, (1 - \exp(-TR/T1_f)) \,.\, \exp(-TE/T2_f)$$

Since water and fat have different relaxation rates, the signals from water and fat will vary depending on the imaging parameters. The effect on the measured fat fraction $FF_{meas} = F / (F + W)$ may be expressed by an amplification factor A defined as FF_{meas} / FF_{true} where the true fat fraction (FF_{true}) represents only the proton densities of water and fat.

Results

Images were acquired following the protocol described in Ref (1), using the HASTE sequence with FS and NFS. A TR of 5000 ms and TEs of 65 ms and 35 ms were acquired. Maps of the FF_{meas} were generated and are shown in Fig 1A and 1B. The change in the measured fat fraction is consistent with a true fat fraction of 0.33 subject to T2 relaxation, as calculated from the plot in Fig 2.

Fig 2 and 3 show the numerically calculated results for the change in FF_{meas} and amplification factor with respect to TE and TR. In both cases the fat fraction is overestimated (i.e. $A \geq 1$). In Fig 4 it is shown that the degree of overestimation also varies with FF_{true} thus, for the same set of imaging parameters, a low fat fraction will be overestimated by a greater percentage than a high fat fraction.

Fig 1: FF_{meas} using TR 5000 ms with (A) TE 65 ms and (B) 35 ms

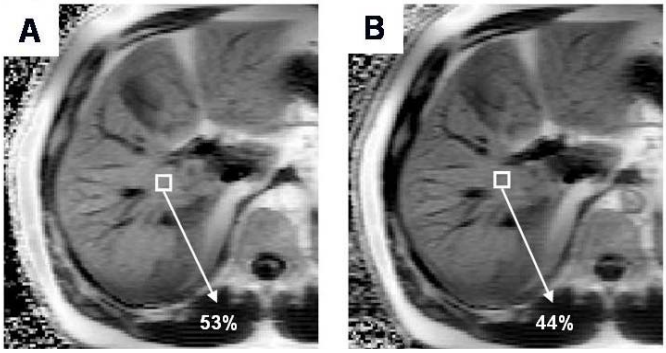


Fig 2: Variation with TE at FF_{true}=0.33

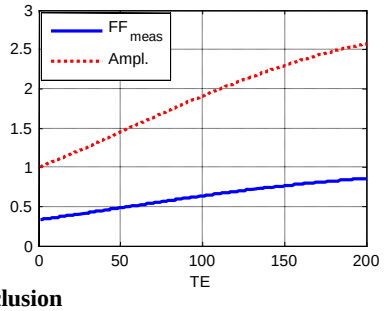


Fig 3: Variation with TR at FF_{true}=0.33

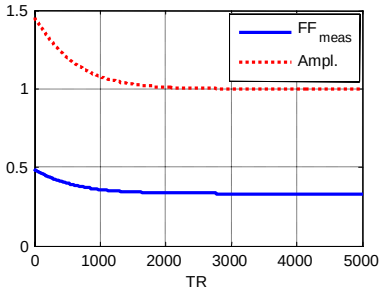
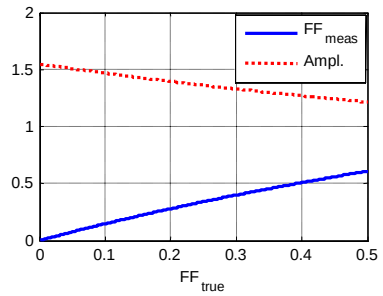


Fig 4: Variation with FF_{true} at TR5000 / TE35



Conclusion

The models as demonstrated in this study, for FSE T1 and T2 weighting and their effects on liver fat quantification with fat saturation techniques have several important implications. The first point of interest is that BOTH have a potential positive error, which, when compounded by choice of suboptimal TR *and* TE values for fat quantification with FSE techniques can be very significant. This is best demonstrated by the Amplification values (Fig 2 and 3). The degree of positive error will vary according to the actual fat fraction present in the liver (see Fig 4). At 1.5T the model implies that a TR of at least 3000ms is required to effectively eliminate T1 weighting from contributing to fat quantification error. This fits with conventional wisdom whereby at least four half lives of T1 decay are required to pass to effectively eliminate T1 effects. Likewise, to minimize error due to T2 decay, the lowest TE possible will give the least error.

These models do not take into account other variables that may contribute to errors in fat quantification using fat saturation and FSE techniques such as inconsistent, inhomogeneous and unquantifiable extent of fat saturation, and variable k-space acquisition. They do, however, emphasize the importance of careful choice of sequence design, in particular the choice of TR and TE for fat quantification using fat saturation FSE techniques.

References

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