A Phantom for Quantitative Fat Imaging

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Introduction: Quantitative fat imaging is becoming important for diagnosis of diseases such non-alcoholic fatty liver disease. Phantoms needed for calibration of pulse sequences have typically been made of oil-water mixtures or emulsions. These phantoms are useful for qualitative work but suffer a number of problems for quantitative verification of estimated fat content. We present here a new type of homogeneous fat phantom that allows any fat concentration.

Methods: Sodium dodecyl sulphate (SDS) is a water soluble surfactant with an NMR spectrum similar to fat. The phantom was made from two stock solutions of 17.7% (w/v) SDS dissolved in H_2O or D_2O. Appropriate volumes of each of these solutions were used to make a series of samples ranging from 10% fat (by mole fraction of CH_2 protons) to 100% fat. Each vial had the same concentration of SDS. The amount of H_20 was adjusted to provide the desired fat/water ratio. Gd was added to create a water proton T_1 of 420 ms. The SDS CH_2 proton T_1 was 200 ms.

Gradient echo imaging was performed on a 2.0 T Varian Inova system. Gradient echo images were obtained at TE = 3.5 ms (in-phase) and 5.24 ms (out-of-phase). TR was set to 138 ms and the flip angle was 20°. The fractional fat percent (FFP) was computed by FFP = (IP – OP)/(2* IP). Magnitude images were used to mimic the data obtained from a clinical scanner resulting in ambiguity of the fat measurement about 50%, i.e. we cannot differentiate between 40% and 60% fat using this method alone.

Results and Discussion: The FFP image is shown in Fig. 1 and a quantitative plot of the measured fat percent vs. the gravimetric fat percent is shown in Fig. 2. These figures show that the method provides a good estimate of fat content from 0% to 70%. The MRI fat measurement of the 90% and 100% fat vials does not fall on the line of gravimetric measure. This is likely not due to a problem with the MRI measurement, but rather with construction of the phantom. Hydrated SDS and addition of Gd create additional sources for water that become problematic at high fat percentages. Actual fat content of the vials needs to be verified by NMR spectroscopy.

Figures 1and 2 show that SNR decreases as fat content increases. This occurs because proton concentration varies from sample to sample. The 10% fat sample has a proton concentration of 122 M whereas the 90% fat sample has a proton concentration of 13.6 M.

Conclusion: This phantom provides the means to quantitatively test the validity of MRI measure of percent fat content. The phantom has many positive features: homogeneity, quantitative control of fat percent, control of water T_1, and the ability to make a phantom of any desired fat content. Care must be taken to assure that there is no water contamination for higher fat content samples. We are working on additional methods to remove the ambiguity of the fat measurement about 50%.

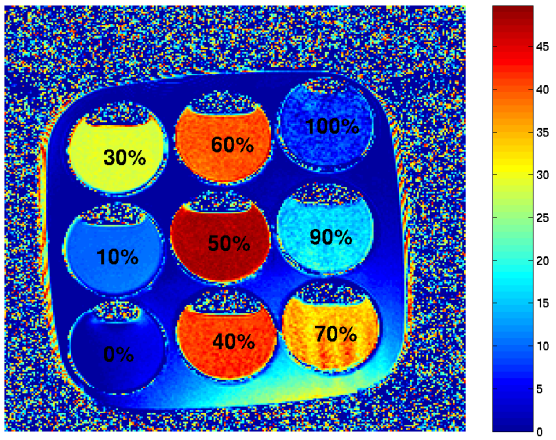

Figure 1. Image of fractional fat percent created from the in-phase and out-of-phase data. The colorbar indicates the quantitative MRI estimate of fat percent. The numbers on the image show the fat percent calculated from the weight of chemicals added to each vial.

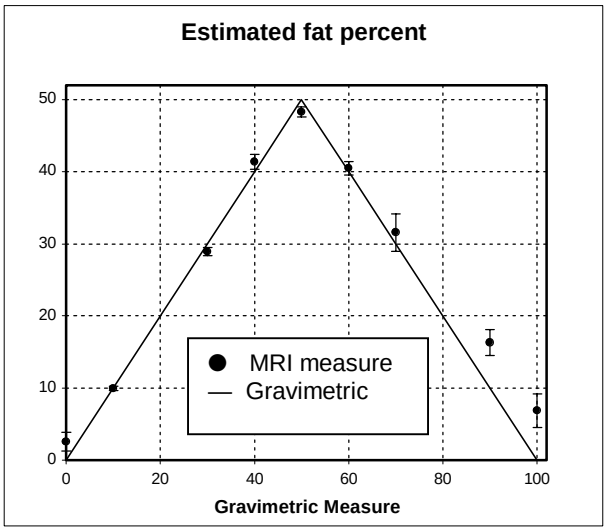

Figure 2. MRI measured fat content vs. gravimetric fat content. Vials labeled 90 and 100% fat contained residual H_2O, leading to erroneous results at these values. NMR spectroscopy is needed to verify gravimetric measures of fat content.