An MR imaging method for quantifying fat fraction

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Introduction: The ability to quantify the hepatic fat fraction of a liver is useful for the diagnosis of Non-alcoholic fatty liver disease (NAFLD) and investigations into donor suitability for live liver transplantation. Liver biopsy is the gold-standard test for these investigations but is invasive and has a significant morbidity. MRI can quantify the fat content of the liver non-invasively using a method first proposed by Dixon [1] and then by Glover [2]. This method uses in-phase and out-of-phase signals to deduce the fat fraction. However the method cannot distinguish whether fat or water is the dominant species. Hussain [3] proposed a solution using two different flip angles to resolve this ambiguity. This method worked well apart from a small region about the 50% fat mark. None of these methods account for the different T1s of fat and water. We propose a method that resolves the fat-water dominant species problem and eliminates any T1-weighting errors.

Theory: The Dixon equation calculates the fat fraction in terms of in-phase signal (S_{ip}) and out-of-phase signal (S_{op}):

$$\text{Fat fraction (FF)} = \frac{S_{ip} - S_{op}}{2.S_{ip}} \text{ (equation 1).}$$

This equation gives slightly offset values for the fat fraction because it does not account for the fact that the T1s of water and fat are different. It does not distinguish whether fat or water is the dominant species present. By considering the signal intensity equation for the gradient echo pulse sequence it is possible to rearrange equation 1 to express the fat fraction as a function of the T1s of water and fat. A least squares fitting method can then be used to fit the equation to data measured at a number of TRs. Thus the fat fraction and the T1 values are obtained. The dominant species can be deduced by noting which of the two fitted T1 variables is shorter.

Method: This algorithm was implemented as a software model. Fat fraction values were generated using the Dixon equation with TRs of 20ms, 40ms, 60ms, 80ms 100ms, 120ms 140ms 160ms, 180ms and 200ms. TRs above 200ms were not considered as this would rule out breath-hold imaging. A T1 of fat of 250 ms, T1 of water of 600ms and T2* of 20ms was used in the model. The in-phase and out-of-phase TE values were 4.76ms and 2.4ms respectively and the flip angle was 70°. The new method was used to calculate fat fractions from this data. To test the algorithm's tolerance random noise was added to the in-phase and out-of-phase signals up to a level of 20%.

Results:

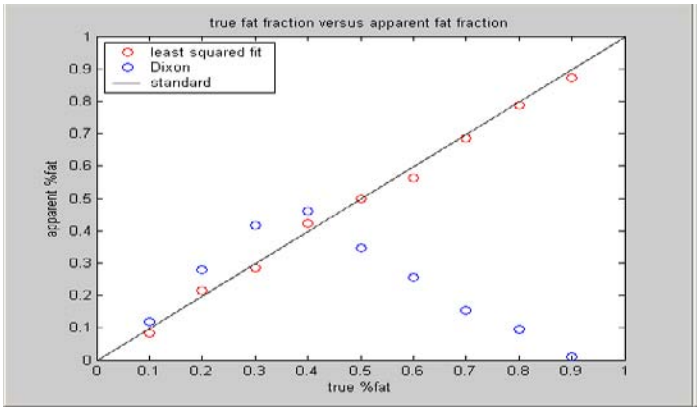

Figure 1. Apparent fat fractions from the new algorithm and the traditional Dixon method (at TR=200ms). The mean error for the new algorithm was 1.8%. The mean error for the Dixon method was 32.6% (6.8% neglecting points above a true %fat of 50%).

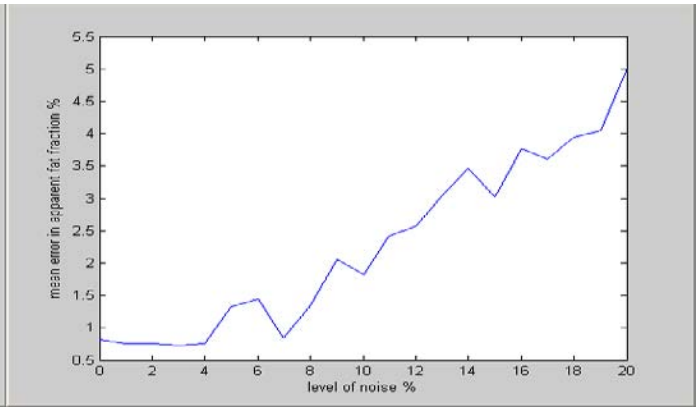

Figure 2. Mean error in apparent fat fraction vs. noise in the MR signal.

Conclusion: A new method for quantifying fat fraction has been tested using a software model. The results suggest that the new method gives a more accurate fat fraction value than the Dixon method and resolves the dominant species ambiguity. The investigation into the tolerance of the method to noise suggests that the method will be able to function tolerably well with a noise level of up to 10%. The disadvantages of the method are that measurements at numerous different TRs will increase the scan time.

References:

1. Dixon. Radiology, 153:189-194 (1984).
2. Glover. JMRI, 1:521-530 (1991).
3. Hussain H.K. Proc. Intl. Soc.Mag. Reson. Med. 11 (2004).